AGRICULTURAL PLANT

PEST MANAGEMENT

Study Guide for Pesticide Application and Safety
Category 1a

Utah Department of Agriculture and Food
Division of Plant Industry
350 North Redwood Road
Salt Lake City, Utah 84114-6500

Revised March 2001

STUDY GUIDE FOR AGRICULTURAL PLANT PEST MANAGEMENT

The educational material in this study guide is provided to assist pesticide applicators in preparing for the agricultural plant category examinations. This guide does not include all the information needed for the agricultural plant examination. Other topics that are covered on the examinations include understanding and following pesticide label directions, emergency response, personal protective equipment (PPE), pesticide movement, mixing and handling pesticides, and application methods and equipment. Information on these and other topics can be found in the following books:

1. ***Applying Pesticides Correctly: A Guide for Private and Commercial Applicators.*** U.S. EPA, USDA and Extension Service, revised 1991.

2. ***Applying Pesticides Correctly: A Supplemental Guide for Private Applicators.*** U.S. EPA, USDA and Extension Service, December 1993, Publication E-2474.

3. ***The Worker Protection Standard for Agricultural Pesticides - How to Comply: What Employers Need to Know***. U.S. EPA, July 1993, Publication EPA 735-B-93-001.

These books can be obtained from the Utah Department of Agriculture and Food (UDAF). Please contact your local UDAF Compliance Specialist or the state office in Salt Lake City. The web site for UDAF Plant Industries is <www.ag.state.ut.us/divisns/plantind/studguid.htm> and the UDAF telephone number is 1-801-538-7185.

The organizations involved in the preparation of this study guide were the Utah Department of Agriculture and Food and Utah State University Extension. This study guide is based on publications developed by the Colorado Department of Agriculture, University Extension personnel of California, Colorado, Idaho, Kansas, New York, Oregon, Pennsylvania, Washington, and Wyoming. Other contributors include the U.S. Department of Agriculture, Forest Service; the U.S. Environmental Protection Agency, Region VIII; and the Department of Interior, Bureau of Reclamation and Metro Pest Management.

The following individuals at Utah State University contributed to the revision of this manual: F.R. Beard, H.M. Deer, S. Thompson, J.B Karren, D.G. Alston, A.H. Roe, and S.A. Dewey.

TABLE OF CONTENTS

I. AGRICULTURAL INSECT PEST MANAGEMENT

TOPIC **PAGE**

INSECT PEST MANAGEMENT

A critical component of agricultural production is the management of insect pest organisms (arthropods). The insects and insect relatives that compete with humans for food and fiber, or attack us directly, are pests. Many of the insect pest problems involving agricultural crops originated with and/or have been aggravated by traditional farming practices. Crop production involves the concentration of host plants and creates an ideal situation for insect development and growth. These enhanced growing conditions lead to a wide range of complex problems without simple solutions.

Insects thrive in more environments than any other group of animals. They live on the earth's surface, within the soil, and in water. Insects populate deserts, rain forests, hot-springs, snowfields, and caves. They compete very successfully with humans for the choicest plants and cause damage to plants in the following ways.

- Feed on leaves,
- Feed on and into fruit, seeds, and nuts
- Feed on and tunnel into roots,
- Tunnel or bore into stems, stalks, branches, and trunks,
- Suck the sap from leaves, stems, roots, fruits, and flowers, and
- Transmit plant disease agents.

The majority of insects are not pests. Many assist humans by pollinating plants and feeding on other insects that are pests. However, most agricultural plants are damaged, weakened, or killed by insect pests. This results in reduced yields, lowered quality, and damaged plants or plant products that cannot be sold. Even after harvest, insects continue their damage in stored or processed products. Insects also feed on and in animals, including humans. Some of these pests carry disease agents that have caused millions of deaths to livestock and humans.

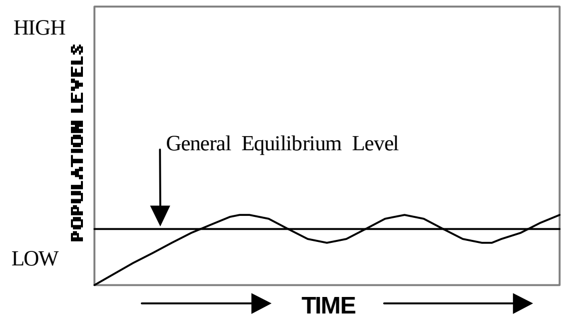
Insect management requires the recognition and understanding of target insect habits, life cycles, and control measures. The first step in controlling insect pests is to properly identify the pest and recognize the problems caused.

ECONOMICS OF INSECT MANAGEMENT

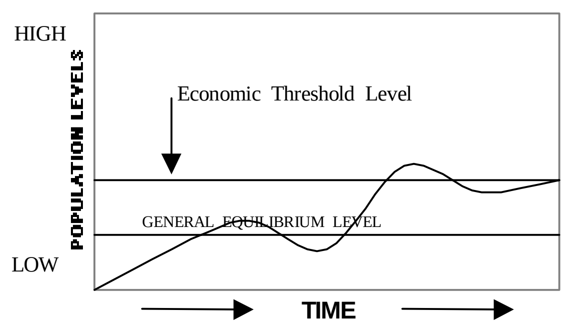
The use of pesticides to control insect pests is a necessary part of large-scale crop production and the decision to treat agricultural crops with an insecticide should be based on economics. To assist with this decision, two phrases related to infestation level are utilized, economic threshold level and economic injury level.

Economic threshold level is the insect population density at which control measures are necessary to prevent an increasing pest population from reaching the economic injury level.

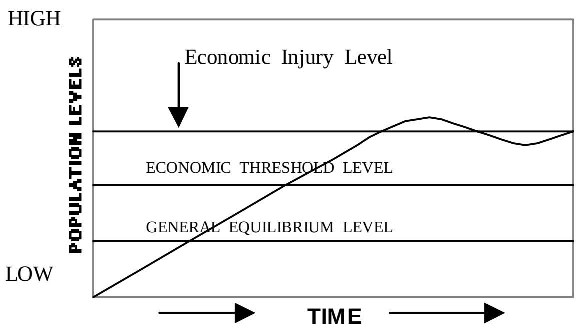
Economic injury level is defined as the lowest population density that will cause economic crop damage. Insect populations normally fluctuate above and below a **general equilibrium level** that represents the average population size. Profits may be slightly affected when pest populations are present at this level.



When pest populations increase to damaging numbers at the **economic threshold level**, control measures must be initiated or increased crop losses occur. At the **economic threshold level**, damage to the crop may justify the cost of control measures.



If control measures are not taken and the pest population continues to increase, the quantity and quality of the crop will be substantially reduced. This point is referred to as the **economic injury level**. This level may vary from crop to crop, area to area, season to season, and/or with the market price of the crop.



It is common practice for preventive treatments to be employed on a calendar basis. Treatment also occurs when insects are initially seen, the **visibility threshold**. Application decisions based on these conditions are justified if there are scheduling problems with equipment or labor, the size of the application area is large, or past experience dictates such practices.

Insecticide applications are best conducted when the pest or evidence of the pest is present in sufficient numbers to reach the **economic threshold level**. When insect infestation reaches the **economic injury level**, the treatment is necessary to prevent substantial loss of the crop.

INSECT CHARACTERISTICS

Knowledge of insect classification, growth and development, and life cycles is necessary for conducting management programs. Proper insect identification is perhaps the most essential step in insect pest management. Life cycle data is also important for scheduling control measures. With proper identification and an understanding of an insect's life cycle, control measures can be applied when the pest is in its most vulnerable stage of development.

The two things that all adult insects have in common are six jointed legs and three body regions. For identification purposes, the important parts to look at are the wings and mouth parts. Some insects have no wings, while others have two or four. The wings vary in shape, size, thickness and structure. Insects with chewing mouth parts have toothed jaws that bite and tear the food. Insects with piercing sucking mouth parts have a long beak that they force into a plant or animal to suck out fluids or blood.

Almost all insects change in shape, form, and size during their lives. This change is called metamorphosis. Some primitive insects change only in size as they develop. A nymph that looks like a tiny adult hatches from the egg and goes through several stages. These nymphs change into wingless adults. The adult lays eggs. Other insects change form slightly. Their nymphs hatch from eggs. The nymphs, having no wings, go through several growing stages and finally change into winged adults.

Other insects change completely. They go through four life stages. Beginning as an egg (stage 1), the larva hatches (stage 2) as a worm, caterpillar, grub or maggot. This is the stage in which insects grow the most and do the most damage. When full grown, the larva changes into a pupa (stage 3). From the pupa stage, it changes into the adult (stage 4). The adult stage usually has wings.

INSECT OUTBREAKS

Insect epidemics or outbreaks are usually caused by:

1. Large-scale culture of a single crop,
2. Introduction of an insect pest into a 3 favorable new area that lacks natural enemies,

3. Favorable weather conditions for rapid de velopment and multiplication of an insect, such conditions may be unfavorable to natural enemies,
4. Use of insecticides that kill the natural enemies of a pest, create other favorable conditions for a pest, reduce competing species of pests, and/or allow it to multiply unmolested or only partially controlled,
5. Use of poor cultural practices that encour age buildup of pest infestations, and
6. Destruction of natural biotic communities that otherwise provide regulation of insect population levels.

INSECT CONTROL TECHNIQUES

Preventive control measures are employed when past experience has shown an insect to be an annual problem. Early season insecticide treatment tends to control certain pest species more effectively. Preventive treatments allow the application of insecticide before the crop foliage is hard to penetrate with sprays, granules, or dusts. Preventive control measures also reduce pest populations before the insects can advance through their stages of development and begin reproduction.

Preventive control occurs prior to the **economic injury level**. Such measures are undertaken with the belief that an insecticide will have to be applied and early application is less expensive and/or more effective than a later application.

Biological control can be defined as the action of parasites, predators or pathogens (disease producing organisms) on an unwanted host or prey population. These agents produce a lower population level than would prevail in their absence. Generally, biological control refers to manipulations by humans, as distinguished from natural enemies and natural control.

Biological control may offer a number of distinct advantages, including permanence, safety, and economy. Once biological control is established, it can be relatively permanent with no side effects such as toxicity, environmental pollution, or use hazards. There are three traditional biological control methods:

1. Introduction of exotic species of parasites, predators, or pathogens,
2. Conservation of parasites or predators, and
3. Increase of parasites or predators.

Natural enemies can assist in controlling the insect pests found in most crop ecosystems, but biological controls are not suitable for many pest situations. It takes time for the parasites and/or predators to bring the pest under control. Normally, a grower who is constrained by markets or economic injury level infestations cannot wait for biological controls to work.

Other technical difficulties involve the determination of which parasites or predators to introduce, whether to use more than one parasitic species at a time, how to eliminate secondary parasites that prey on the beneficial form, and whether a program of continuous releases may be feasible. Also, there is the problem of protecting such predators and/or parasites from insecticides.

Mechanical control is the reduction of insect populations by means of devices that affect them directly or alter their physical environment radically. These methods are often hard to distinguish from cultural methods. However, mechanical controls involve special physical measures rather than normal agricultural practices. They tend to require considerable time and labor and often are impractical on a large scale.

Hand picking and trapping are familiar mechanical methods of insect control. Screens, barriers, sticky bands, and shading devices are also mechanical methods or devices. Hopper-dozers and drags are stypes of specialized control equipment for collecting or smashing insects.

Legal control is the lawful regulation of areas to eradicate, prevent, or control infestation in order to reduce the damage by insects. This mainly involves the use of quarantines and pest control procedures. Federal and state officials often work with legally established local, community, or county districts, as in grasshopper control projects.

Cultural control is the reduction of insect populations by using agricultural practices. It has also been defined as "making environments unfavorable for pests." These methods, more or less associated with agricultural production, usually involve certain changes in normal farming. practices rather than the addition of special procedures.

Scheduling cultural practices to occur during the most vulnerable time of an insect s life cycle is a very effective control measure. The insect s favorable environment is altered to kill the pests or reduce their reproduction. Since cultural methods are usually economical, they are useful against field crop insects.

Types of cultural control practices are:

1. **Rotation**: Certain kinds of crop rotations may help control pests. Insects that are reduced effectively by rotations usually have a long life cycle and a limited host range and are relatively immobile in some stage of their development. Changing crops in a rotation system isolates such pests from their food supply. Wireworms, white grubs, and corn rootworms are good examples.
2. **Location**: Careful choice of crops to be planted adjacent to each other may help reduce insect damage.
3. **Trap crop**: Small plantings of a susceptible or preferred crop may be established near a major crop to act as a "trap." When the insects have been attracted to the trap crop, they are treated with insecticides, plowed under, or both.
4. **Tillage**: The use of tillage operations to reduce populations of soil inhabiting insects may work in several ways. Tillage can change the physical conditions of the soil; bury, expose, or mechanically damage the insect at a particular stage of life; eliminate insect host plants; and hasten growth or increase vigor of the crop.
5. **Sanitation:** Removing crop residues, disposing of volunteer plants, and burning chaff stacks are measures commonly applied against vegetable and field crop insects.
6. **Timing**: Changes in planting time or harvesting time are used to keep the infesting stage of an insect separated from the susceptible stage of the host.
7. **Resistant varieties**: The sources of resistance to insects in crops have been classified as nonpreference, antibiosis, and tolerance. Insect **nonpreference** for a certain host plant is related to color, light reflection, physical structure of the surface, and chemical stimuli such as taste and odor. **Antibiosis** is the adverse effect of the plant on the insect. This may be caused either by the harmful effect of a specific chemical or by lack of a specific nutrient requirement.

Tolerance is the term applied to the general vigor of certain plants that may be able to withstand the attack of pests such as sucking insects. Tolerance also includes the ability of the plant to repair tissues and recover from an attack.

Advantages of the use of resistant varieties include a cumulative and persistent effect which often eliminates insect damage within a few seasons, lack of dangers to humans and domestic animals, low cost (once the program is established), and usefulness in integrated control systems.

Reproductive control is the reduction of insect populations by means of physical treatments or substances that cause sterility, alter sexual behavior, or otherwise disrupt the normal reproduction of insects.

Chemical control is the reduction of insect populations or prevention of insect injury by the use of insecticides to poison them, attract them to other devices, or repel them from specified areas.

In most cases, despite adverse publicity, insecticides are the most effective method of managing insects. Insecticides are highly efficient and economical, and they can be applied quickly and have an immediate impact on insect populations. When insect populations approach economic threshold levels in market crops, and natural controls are inadequate, insecticide applications are the only option.

Insecticides are essential for:
1. Maintaining adequate crop protection,
2. Protecting forest resources, and
3. Preserving the health and well being of humans.

An advantage of using insecticides in many crop ecosystems is that more than one major insect can be controlled with a single application. Chemical insecticides are especially important as fast-acting insect management tools. Insecticides should be used in a manner that is harmonious with other elements of the agricultural ecosystem so that they amplify other control agents. Insecticides have the following limitations:

1. Insecticides contribute to the development of insects resistant to chemical control,
2. Insecticides temporarily control insect populations, but often require repeated treatments,
3. Insecticide residues are restricted when present in harvested crops,
4. Insecticides unleash secondary pests resulting from the destruction of their natural enemies,
5. Insecticides have undesirable side effects on nontarget organisms such as parasites and predators; fish, birds, and other wildlife; honeybees and other necessary pollinators; domesticated animals; humans; and crop plants,
6. Insecticides present a hazard to the applicator, and
7. Insecticides reduce and simplify the arthropod component of the agricultural ecosystem.

Integrated pest management (IPM) is the management of insect populations by the use of all suitable techniques in a compatible manner so that damage is kept below economic threshold levels. Principal considerations of the IPM approach to insect management are the agricultural ecosystem, the economic threshold, and the least disruptive program, with some emphasis placed on biological control agents such as beneficial insects.

FIELD CROP INSECTS

ALFALFA INSECTS

The alfalfa weevil is considered to be a serious threat to the production of alfalfa in all areas of Utah. The majority of the damage occurs during the time when the first alfalfa cutting is being produced, but damage by larvae as well as adults may also delay regrowth. Feeding injury is evident by the skeletal appearance of the fully expanded leaflets in the top third of the plants.

OTHER CROP INSECTS

There are numerous insects and insect relatives that damage corn and small grains in Utah. They include: corn earworm, cutworm, red spider mite, cereal leaf beetle, grasshopper, Russian wheat aphid, and a variety of others. A list of major insect pests in Utah appears in Appendix 1.

FRUIT TREE INSECTS

In Utah, most of the important insect pests of fruit trees feed in or on the developing fruit. Examples include the codling moth on apples and the oriental fruit moth on peaches. Damage is caused either by feeding on the surface or by boring inside the fruit to feed. This damage can cause fruit to drop prematurely or make it less acceptable to consumers, thus reducing its market value.

Exception to the fruit feeding pests are those that feed mostly on the leaves, twigs, limbs, or trunks of the trees. Examples are mites, scales, and the peach tree borer. Feeding by these insects can threaten the vitality of trees. Appendix 1 lists the major tree fruit insects in Utah.

VEGETABLE CROP INSECTS

Insects are perpetual pests in vegetables. Some begin feeding as soon as the seedlings emerge, while others attack the growing plant, feeding on both the foliage and the fruit. Many insects build up to very large numbers and are capable of completely destroying various crops. Appendix 1 lists the major insects that damage Utah vegetable crops.

Healthy, vigorously growing plants are less susceptible to insect attack. Therefore, proper irrigation, fertilization, weed control, and disease control can help hold down insect damage. When insect damage is detected, the insect pest must be correctly identified and the insecticide treatment must provide thorough coverage of the plant to achieve control.

Most insecticides used on vegetables have a short residual, so more treatments may be needed if pest recurrence is a problem. Excessive use of insecticides should be avoided to prevent toxicity to plants and excessive residue on crops. Vegetable pests can be placed into three general groups:

1. **Soil insects** usually attack either the seed at planting time or small, tender plants. However, they may attack larger plants such as carrots or potatoes.
2. **Sucking insects** damage plants by inserting their mouth parts into plant tissue and removing plant juices. Some sucking insects inject toxic materials into the plant while feeding and some transmit disease organisms to plants.
3. **Chewing insects** can cause more damage to vegetables than either soil or sucking insects. They feed on all parts of plants and destroy both foliage and fruit. A wide range of chewing insects attack plants.

RANGELAND INSECTS

Insect management, especially grasshopper control, is an important component of rangeland and pasture management throughout Utah. Grasshoppers are the single most destructive insects found on Utah rangelands. When grasshoppers are present in large numbers they exert a significant destructive influence on rangeland and pasture vegetation.

Grasshoppers have a biotic potential for sudden and explosive population increases. The severity of a grasshopper outbreak depends on the populations of preceding years, temperature, and moisture conditions at the time of hatching. Factors that restrict the increase of grasshopper populations include unfavorable weather conditions, lack of food, natural enemies, and disease.

Grasshopper outbreaks that exceed a population four times that of the previous year are common. During severe outbreaks, increases exceeding 10 times the previous year's population sometimes occur, resulting in 100 or more grasshoppers per square yard. At this level of infestation, crops and native vegetation will be entirely devoured if control measures are not employed.

Grasshoppers in rangeland habitats have beneficial roles in the rangeland ecosystems. Research has shown that range grasses are stimulated by some grasshopper feeding. The grasses fed on by grasshoppers produced more growth and biomass than plants that were totally protected.

The saliva, droppings, and unknown factors from grasshoppers stimulate plant growth. The uneaten cuttings of leaves and other plant parts should not be considered all waste. This activity produces litter that helps retain soil moisture and provides nutrients for plant retain soil moisture and provides nutrients for plant growth. Furthermore, grasshoppers are an important animal food source for many omnivorous as well as insectivorous mammals, birds, and fish.

The actual dollar effect of a grasshopper infestation on range livestock productivity varies greatly from year to year. Damage caused by grasshoppers goes beyond actual consumption of forage. They cut grass stems and blades, eating only a part of them; they eat closer to the ground than livestock and feed primarily on the growing part of grasses; and they cut off the seed stalks reducing seed production.

MANAGING RANGELAND INSECTS

Rangelands are a valuable natural resource for livestock production, wildlife habitat, watersheds, recreation, and assorted diverse economic interests that are intimately associated and interdependent. The objective is to save current rangeland forage by reducing infestations to below economic threshold levels. The points to consider when undertaking such a task are:

1. **Economic infestation**: Does current target pest survey data indicate economic-level population densities over most of the proposed treatment area?
2. **Timing**: Is the proposed insecticide treatment going to be applied late enough for most of the pests to have hatched and before egg-laying and/or migration occurs?
3. **Protecting pollinating insects**: Insecticides currently used to control range insects are very hazardous to all bee pollinators. Every effort must be made to protect bees from exposure.

II. AGRICULTURAL WEED MANAGEMENT

WEED MANAGEMENT

A weed is an unwanted plant or a plant growing in the wrong place. This designation is based on human preferences and requirements. Usually a plant is considered a weed when it interferes with land or water resources or it grows in a location where other plants are desired. Agricultural weeds are divided into two basic groups, grass and broadleaf.

GRASS

Grasses are narrow-leave plants that generally grow upright and have parallel veins in the leaves. Young grass seedlings have one leaf that emerges from the seed. Many grasses have a fibrous root system, while others have rhizomes or stolons. Agricultural producers consider the following grasses to be weeds: common sandbur, barnyard grass, green foxtail, wild oats, jointed goatgrass, quackgrass, Johnson grass, and wild proso millet.

BROADLEAF

Broadleaf plants generally have broad, net-veined leaves. The root systems have either a single taproot or an extensive root structure that spreads both vertically and horizontally. Agricultural producers consider the following broadleaves to be weeds: field bindweed, Canada thistle, musk thistle, whitetop, Russian knapweed, tansy mustard, and burdock.

For an extensive publication on the weeds found in Utah, the book "Weeds of the West" may be purchased from Utah State University Extension <www.ext.usu.edu>. If there is a question regarding the proper name or identification of a plant, a specimen can be submitted to a local county extension office for identification.

UTAH LEGISLATION CONCERNING WEEDS AND WEED SEEDS

The Utah Seed Law is aimed at controlling the spread of noxious weed seeds and the noxious weeds. This law applies to agricultural, vegetable, and ornamental seed that is sold, bartered, or distributed in Utah for seeding purposes. Noxious weed seed refers to seeds produced by especially troublesome and detrimental plants that may cause damage or loss to a considerable portion of the land or livestock of a community.

There are two classifications of a noxious-weed seed: prohibited noxious weed seed and restricted noxious weed seed. Seed sold for planting purposes must be clean of all prohibited noxious weed seeds and cannot contain more restricted noxious weed seeds per pound than listed in the rules and regulations in R68 8 and Title 4, Chapter 17. Prohibited or restricted weeds and seeds that fall under the Utah Seed Law (R68 8) and the Utah Noxious Weed Act (Title 4, Chapter 17) can be found in Appendix 2.

PLANT LIFE CYCLES

ANNUALS

Annuals are plants that complete their life cycles in one growing season and can only propagate by seed. Summer annuals germinate in the spring, develop and set seed in the summer, then die before winter. Common summer annuals are Russian thistle, redroot pigweed, kochia, lambsquarters, and barnyard grass. Winter annuals germinate in the late summer or fall, overwinter, then resume growth in the spring. By summer, they flower, set seed, and die. Common winter annuals are downy bromegrass, prickly lettuce, tansy mustard, and wild oats.

BIENNIALS

Biennials require two years to complete their life cycles. These plants develop from seed and grow without flowering the first year. Usually the first year's growth results in a cluster of leaves, or rosette, close to the ground. In the second year, the plant flowers, produces seed, and dies. Common biennials are musk thistle, mullein, burdock, and mallow.

PERENNIALS

Perennials are plants that can live three years or longer. They can propagate by seeds, by runners, from stems above the ground (stolons), or by underground stems that develop roots and leafy shoots (rhizomes). These plants can flower and set seed each year, die back to the ground during the winter, then resume growth in the spring. Common perennials are Canada thistle, field bindweed, whitetop, Russian knapweed, and quackgrass.

WEED MANAGEMENT PLAN

In order to develop a successful weed management plan, the objectives must be clear and practical. The strategies of this plan involve the techniques of prevention, eradication, and/or management.

PREVENTION

Prevention includes all the measures taken to avoid or delay the introduction and spread of weeds. This will include good farm-management techniques and, if necessary, legislative control. Preventive control measures should be adopted whenever practical and should be the first step in a weed-management program. There are several preventive measures that agricultural producers can take.

1. Always use certified weed free seed.
2. Do not feed grains or hay containing weed seeds.
3. Do not spread manure while weed seeds are still viable.
4. Do not move livestock directly from land where weeds are present to weed free areas.
5. Avoid moving soil and debris from weed infested areas to weed free areas.
6. Make sure agricultural equipment is cleaned before moving it from weed infested areas.
7. Inspect nursery stock for weed seeds and other weed parts.
8. Keep irrigation ditches, fence lines, roadsides, and other noncrop areas free from weeds.
9. Whenever a new weed infestation is identified, especially a small infestation immediately begin weed control efforts before spread occurs.

Preventive measures can also be carried out through legislative action. Statewide noxious weed control laws can mandate control of troublesome weed species and help stop the spread of noxious weeds within a state. Additional legislative action, such as mandating that farm equipment transported into the state be clean of weed seeds, further helps prevent the spread of weeds.

ERADICATION

Eradication means the complete removal or destruction of the living plants, roots, and seeds from an area. This is practical for small infestations, but it is not practical for the majority of weeds that infest large areas of land. For many weed species, maintenance control programs on an annual basis are necessary because of the duration of seed viability in the soil. For example, field bindweed seeds may germinate after 40 years in the soil. Most weed seeds will stay viable in the soil for longer than five years.

MANAGEMENT

Management is the process of containing and limiting weed infestations. A principle of weed control is to reduce the infestation and minimize the competitive effect on a crop. A weed management strategy is more practical than eradication when dealing with extensive infestations.

WEED MANAGEMENT TECHNIQUES

Weed management techniques include cultural, mechanical, biological, and chemical controls. An integrated weed management (IWM) approach utilizes two or more of these techniques. IWM is the most effective and economical approach to agricultural weed management.

CULTURAL

Crop competition and crop rotation are two cultural controls that can be very effective in weed management and are inexpensive. Competition involves choosing a suitable crop and using the best production methods so the crop outgrows the weed, minimizing the weed growth and spread.

An example of competition is the use of alfalfa to compete with Canada thistle. A dense seeding of alfalfa in the fall with good crop establishment in early spring can help shade, crowd, and ultimately reduce both the vigor and density of Canada thistle. Using a nonresidual broadleaf herbicide on the Canada thistle before alfalfa seeding will produce even better results.

The presence of a weed infestation is one of the factors considered in the selection of a rotation crop. A rotation crop should crowd out a weed or allow other methods of weed management such as tillage, herbicides, or fallow to be implemented.

An example of when crop rotation is needed is corn infested with wild proso millet. Control of wild proso millet in corn is very difficult with mechanical means and costly with herbicides. Rotating into beans or onions would allow the use of less costly herbicides or continued mechanical methods throughout the season.

MECHANICAL

Mechanical control includes cultivation, mowing, hoeing, hand pulling, and root plowing. All of these methods involve the use of tools to physically cut off, cover or remove undesirable plants from the soil. Cultivation or tillage is the most common method of weed control. This method is effective for small annual weeds, but less effective for the larger annuals. Tillage can also be used for controlling perennial weeds. Frequent tillage operations every 10 to 14 days for two or more seasons is required for the control of most perennial weeds.

The use of fire is another mechanical method of controlling weeds. Fire can be an effective tool for removing vegetation from ditch banks, roadsides, fence lines, and other areas. Fire can be used in the fall to burn off the trash of dried weeds that are remaining. If the weed seeds are still remaining on the plant, burning can reduce the number of viable weed seeds. Burning does not destroy the majority of seeds that have fallen to the ground.

The use of flooding as a weed management measure temporarily reduces the oxygen concentration in the soil. Seeds need a certain concentration of oxygen to germinate; therefore, use of flooding in the spring could reduce the number of weed seeds germinating. Use of flooding is not practical in many agricultural situations.

BIOLOGICAL

Biological control of a weed may involve using natural enemies, such as insects and plant diseases. Grazing of weeds by livestock is also a form of biological control. Generally speaking, biological control works best on large infestations of a weed. In most agricultural situations, the effectiveness of biological control is limited because of intensive farming practices.

A good example of biological control is the establishment of the seedhead weevil, *Rhinocyllus conicus*, on musk thistle throughout Utah. Another example is the use of sheep to feed on leafy spurge, especially when it is in the seedling stage. Biological controls will not eradicate a weed population, but they can reduce density and size of infestations.

CHEMICAL

Chemical control involves the use of herbicides to kill or inhibit plant growth. The use of herbicides by humans for weed control dates back to the turn of the century, when iron sulfate, copper nitrate, and solutions of sulfuric acid were used. In the 1940s, 2,4-D was developed as a selective herbicide. Since that time, hundreds of herbicides have been developed.

INTEGRATED WEED MANAGEMENT
IWM is the use of two or more weed control techniques in a management program. Often the use of two or more methods will result in better overall weed management. The selection and implementation of weed management techniques depends on ecological, agronomic, and economic factors.

For management of perennial weeds, combined efforts of cultural, mechanical, biological, and chemical methods will produce better results than the use of a single control technique.

RANGELAND WEED AND BRUSH MANAGEMENT

Much like crop producers, good weed and brush management practices are required for livestock producers to maintain and improve the productivity of rangeland. Many of the methods and practices employed for crop production are also effective for range and pasture management.

Nonproductive weeds and brush invade rangeland as the desirable native species are weakened or thinned out by practices or conditions such as overgrazing or erosion. There are several problems that occur when weeds and brush infest pasture and rangeland.

The first problem is the takeover factor. Once weeds and brush become established, they spread rapidly. The yield potentials and carrying capacity of these lands decline.

The second problem is poisonous plant hazards. In many cases, plants that invade abused rangeland are toxic to livestock. In the 17 western states, losses by livestock producers to toxic plants are estimated to be $107 million annually. When considering livestock abortions, birth defects, poor gains, chronic illness, and other problems caused by poisonous plants, the figure is much larger. In the western states, almost nine percent of nutritionally sick animals are ill from eating poisonous plants.

A third problem is the reduction in the efficient use of range when brush takes over. It becomes virtually impossible to manage livestock in areas overgrown with such vegetation. Furthermore, it may be necessary to increase the number of breeding males in order to maintain acceptable birthrates.

Other sources of infestation or reinfestation include nonrange and noncrop areas such as transportation and utility right of ways, roadsides, field borders, fence lines, and areas around farm and ranch buildings. It is here that weed seeds often originate and, if not managed, the surrounding lands become infested.

CLASSES OF HERBICIDES

Most herbicides are classified as either organic or inorganic, with most of the compounds being organic. Some of the common classes of herbicides follows:

PHENOXIES
The phenoxy herbicides are widely used in both crop and noncrop areas for control of most annual and perennial broadleaf weeds. Some commonly used phenoxies include: 2,4-D (amine and ester formulations), MCPA, dichlorprop (2,4-DP), and 2,4-DB (Butoxone or Butyrac). The phenoxies are primarily applied as a postemergence treatment to the foliage of actively growing weeds. Entrance into plants through

root uptake is also possible. The phenoxies are primarily plant growth regulators and affect the actively growing tissue of the plant. The ester formulations of the phenoxies are relatively volatile and turn into a gas during hot summer days. Care should be taken not to use them around susceptible broadleaf crops and ornamentals.

TRIAZINES

The triazines are used in a number of crops and in orchards and shelterbelt areas to control annual grasses and broadleaf weeds. Some commonly used triazines include atrazine (AAtrex), simazine (Princep), and metribuzin (Sencor or Lexone). The triazines are often applied as a pre-plant or pre-emergence incorporated treatment. Prometon (Pramitol) is a nonselective pre-emergence and post-emergence herbicide used on noncrop land. The triazines affect plants by inhibiting their ability to photosynthesize. The triazines have been used so extensively in certain crops, such as corn, that resistant weed species have developed. Resistant biotypes of kochia have been identified in Utah.

THIOCARBAMATES

The thiocarbamates are used on cropland and on ornamental plantings for control of annual grass seedlings and broadleaf weed seedlings. EPTC (Eptam) is a commonly used thiocarbamate. The thiocarbamates are applied as a pre-plant, soil incorporated treatment. They inhibit the meristematic growth of plants, such as root and shoot tips. Most thiocarbamates are relatively volatile and must be incorporated into the soil.

UREAS AND URACILS

The ureas and uracils have several similar uses and their modes of action have many features in common. Many of the compounds found in these two classes of herbicides are used at lower rates than other herbicides in crop and noncrop areas for control of annual grass seedlings and broadleaf weed seedlings. Some of the compounds are used at higher rates as a nonselective, bare ground product. Diuron (Karmex) and tebuthiuron (Spike) are commonly used ureas and bromacil (Hyvar) is a widely used uracil. These compounds are primarily used as soil applied, pre-plant or pre-emergence herbicides, but they also provide post-emergence control for certain plants. The ureas and uracils affect plants by inhibiting their ability to photosynthesize.

BENZOICS

The benzoic acid herbicides are used in both crop and noncrop areas for control of numerous broadleaf weeds and annual grasses. A commonly used benzoic is dicamba (Banvel or Clarity). The benzoic herbicides are effective when applied either foliar or to the soil. The benzoics are plant growth regulators similar to the phenoxies. They affect the actively growing tissues of plants.

ACETANILIDES

The acetanilide herbicides are used in numerous crops and in some ornamentals for control of many annual grasses and broadleaf weeds. Common acetanilides include alachlor (Lasso), acetochlor (Harness or Surpass), metolachlor (Dual), and pronamide (Kerb). The acetanilides are used as selective herbicides in crops such as corn and sorghum. They are applied as either a pre-emergence or pre-plant treatment.

SULFONYLUREAS

This class of herbicides is one of the most recent to be developed. The sulfonylureas are highly active compounds used at extremely low rates. They are used mainly to control many broadleaf species in small grain crops, pastures, and noncrop areas. Commonly used sulfonylureas include chlorsulfuron (Glean and Telar), triasulfuron (Amber), sulfometuron (Oust), and metsulfuron (Ally and Escort). These compounds are usually applied as foliar treatments; however, they also control newly emerging broadleaf seedlings. Chlorsulfuron and sulfometuron are sulfonylureas that are more persistent in nature and will carry over into a second year when applied in high-pH soils. Care must be taken when using these compounds around certain crops such as corn, sugar beets, and potatoes. Extremely low residues from wind drift or in wind blown soil can cause significant crop loss.

IMIDAZOLINONES

A new and important herbicide family is the imidazolinones. It includes imazethapyr (Pursuit), imazamethabenz (Assert), and imazapyr (Arsenal).

HERBICIDES BY USE

Herbicides can be conveniently classified by their selectivity, which is how they affect the target and nontarget vegetation. They also may be classified by use, whether they are applied to the soil or foliage of the plant. Herbicides affect plants in different ways. Some herbicides work strictly by contact with the leaf and stems of the plant, while others may be taken up by the roots or leaves of a plant and translocated throughout the plant, acting systemically. Some herbicides used at lower rates may help regulate the growth of the plant and production of the seed, while at higher rates, they will kill plants.

SELECTIVE HERBICIDES

The primary role of a selective herbicide is to remove unwanted vegetation (weeds) from an area, whether it be in a crop, range or pasture, without affecting the surrounding vegetation. Some selective herbicides such as 2,4-D, dicamba and picloram are applied to the foliage of the plant, while other herbicides such as atrazine, trifluralin, and oryzalin are applied to the soil.

NONSELECTIVE HERBICIDES

Nonselective herbicides are chemicals that are phytotoxic to most plant species. These compounds are generally used where either no vegetation is wanted, such as along transportation and utility rights of way or ditches, or where it is necessary to destroy the top growth of a crop such as with potatoes. Compounds like glyphosate, which have no soil residual, are used in crop systems as a chemical fallow treatment. Commonly used nonselective herbicides include glyphosate, imazapyr, bromacil and paraquat. When using the longer residual non selective herbicides such as bromacil, diuron or tebuthiuron, extreme caution should be taken around crops, trees or water.

Do not apply any of these herbicides on sloping land where there is potential of washing the herbicide into nontarget vegetation or water. Treated soil should not be moved or used for other purposes unless tested and found free of residue. Care must be taken when applying any herbicide. Most selective herbicides can become nonselective as a result of over application.

CONTACT HERBICIDES

Contact herbicides are applied to the foliage of plants. These herbicides affect only the part of the plant they contact. Usually complete coverage of the plant is necessary for good control. Most contact herbicides are nonselective. Bromoxynil, paraquat, and diquat are commonly used contact herbicides.

TRANSLOCATED HERBICIDES
Herbicides that move from one part of the plant to another such as from the leaf to the roots are translocating or systemic herbicides. Herbicides that move from the leaf surface and flow to the root through the phloem follow the same pathway as sugar that is formed by photosynthesis. Herbicides that are absorbed by the root enter the xylem and move throughout the plant, following the same path as transpirational water.

Translocating herbicides may be either soil or foliar applied or both, depending on the herbicide and its route of action. Some herbicides will move exclusively through either the foliage or the roots, while other herbicides can move equally through both systems.

Translocating herbicides are an important tool in controlling perennial weeds, which have extensive underground root systems that are hard to kill. Some commonly used foliar-applied herbicides which translocate into both foliage and roots include: MSMA, glyphosate, dichloprop, 2,4-D, dicamba, picloram, and chlorsulfuron.

Commonly used soil-applied herbicides that primarily translocate through root uptake are simazine, diuron, pronamide, and EPTC. A number of the triazines and thiocarbamates will translocate through both processes; however, they primarily work through root uptake because of the recommended method of application.

PLANT GROWTH REGULATORS
Plant growth regulators (PGR) are herbicides used for regulating or suppressing the growth of a plant and/or its seedhead production. Some of the PGR herbicides such as mefluidide (Embark) strictly suppress the growth and seedhead production of certain grasses and do not have any phytotoxic effects on other grasses or broadleaf plants in general. Sulfometuron (Oust) is a herbicide that causes growth and seedhead suppression on certain grasses and controls many annual broadleaf weeds as they germinate in the soil. An example of a herbicide used as a growth suppressant of many brush species is fosamine ammonium (Krenite). These herbicides are generally applied to the foliage of the plants.

FACTORS AFFECTING FOLIAR APPLIED HERBICIDES

BIOLOGY OF WEEDS
Grass and broadleaf weeds go through stages of growth in which they are more or less susceptible to herbicides. Proper timing of a herbicide application is important for effective plant control. The basic stages of plant growth are seedling, vegetative, bud and flowering, and maturity. These stages vary between annual, biennial, and perennial plants.

Seedlings
Whether looking at annual, biennial or perennial weeds, the seedling stage of growth is the same, they all start from seed. The weed seedlings are small and tender, so less energy is required for control at this stage of growth than at any other. This is true whether mechanical or chemical control is used. Herbicides that are foliar or soil applied are usually very effective at this stage of growth.

Vegetative
During the vegetative stage of growth, energy produced by the plant goes into the production of stems, leaves, and roots. Control at this stage

is still possible but sometimes harder than at the seedling stage of growth. At this stage, a combination of cultivation, mowing, and herbicide applications offer effective control.

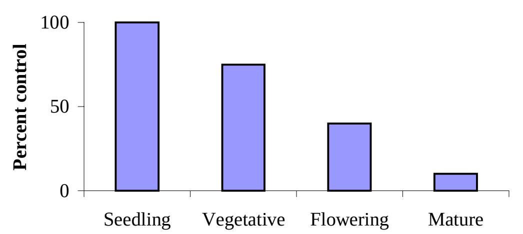
ANNUALS

Flowering

When an annual plant changes from the vegetative to the flowering stage of growth, most of its energy goes into the production of seed. As plants reach this more mature stage, they are usually much harder to control by chemical methods.

Maturity

When an annual plant has produced seed, it has completed its life cycle. Once seeds are produced, mechanical or chemical control methods are not effective, since neither method will destroy the seed.



Weed control of annuals by growth stage

BIENNIALS

Vegetative

Biennials are plants that complete their life cycles in two years. Most biennials develop a rosette, a cluster of crowded leaves close to the ground, in their first year. The rosette can be seen in the fall and in the spring of the following year. Best control of biennials with the use of herbicides can be achieved during this growth stage.

Bud to Flowering

Effective control of biennials with herbicides can be achieved when the plant is in the bud to early flower stage.

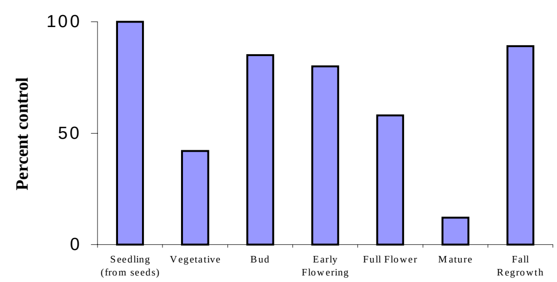
Maturity

When a biennial plant has produced seed, it has also completed its life cycle, just like the annual plant. Mechanical or chemical control measures would once again not be effective at this stage of growth, since the seeds would not be affected.

PERENNIALS

Vegetative

Most systemic foliar herbicides translocate within plants in much the same pattern as sugars. The most effective herbicide applications coincide with the time when the greatest abundance of sugars is being translocated to the roots. When the plant is small, much of the energy used to produce stems and leaves comes from the sugars and starches stored in the underground roots and stems. Herbicide treatment at this time provides only fair results. As the plant grows, more energy is produced in the plant leaves. Some of these nutrients are moved to the underground parts for growth and storage. Herbicide treatment at this time provides fair results.



Weed control of perennials by growth stage

Bud to Flowering

At this stage, the plant's energy goes into the production of flowers and seeds. Food storage in the roots begins during this stage and continues into maturity. Chemical control is generally more effective at the bud stage than at the flowering stage. This is an excellent time to apply a systemic foliar herbicide.

Maturity.
During the period between the production of seed until the fall regrowth, perennial plants go into a time of senescence or aging. The plant is not feeding its root or growing, and therefore chemical control at this time is not very effective. When fall approaches, the plant becomes active again and starts sending nutrients (food reserves) down to the root to store for the winter. Fall regrowth is another excellent time to chemically treat perennial weeds, since the plant will readily translocate the herbicide down throughout the root.

PHYSICAL CHARACTERISTICS OF PLANTS AFFECTING HERBICIDE EFFECTIVENESS

The physical characteristics of plants such as leaf shape, cuticle layer of the leaf surface, and leaf hairs affect the ability of herbicides to gain entrance into the plant. By considering each factor, more effective control is achieved.

Leaf Shape
Leaf shape affects the amount of herbicide that may enter the plant. Herbicide sprays tend to bounce or run off plants with narrow, upright leaves such as grasses. Most broadleaf plants have wide smooth leaf surfaces that are parallel to the ground and hold the herbicide spray on the leaf surface.

When spraying grasses or other narrow leafed weeds, some herbicide labels may suggest adding a surfactant (spreader or sticker) to the spray to help the spray solution to adhere to the leaf surface and therefore increase the effectiveness of the herbicide.

Cuticle Layer
All plants have a waxy leaf surface called a cuticle. The cuticle restricts the movement of water and gasses in and out of the leaf. The cuticle thickness will vary within the same species, depending on the environmental condition each plant is exposed to. Plants growing in the shade often have thinner cuticles than those growing in the sun and younger leaves usually have thinner cuticles than older leaves.

The waxy cuticle layer affects the absorption of the herbicide by the plant. The herbicide must penetrate the leaf surface to be effective. A leaf with a thin cuticle layer allows the spray solution good contact with the leaf surface with resulting absorption. However, on a leaf with a thick waxy cuticle layer, the spray solution tends to stand up in droplets and has more difficulty penetrating the waxy cuticle layer. Adding a nonionic surfactant (wetting agent) to the spray solution (if instructed to do so on the label) is important when treating any plant that has a thick cuticle layer.

Leaf Hairs
Hairs on the leaf surface also tend to keep the spray solution from making contact with the leaf surface. Droplets are formed and are suspended by the hairs. Adding a nonionic surfactant (wetting agent) to the spray solution (if instructed to do so on the label) is important when treating any plant that has leaf hairs. A nonionic surfactant will break the surface tension of the water droplets and improve the spread of the spray solution over the leaf surface. Many foliar herbicides already have a surfactant added to the formulation.

FACTORS AFFECTING SOIL APPLIED HERBICIDES

SOIL CHARACTERISTICS

The physical and chemical characteristics of the soil as well as the climatic conditions will determine the effectiveness of a soil applied herbicide, the persistence of the herbicide in the soil, and the potential movement of the herbicide through the soil (leachability).

One of the properties of soil particles, as well as herbicides, is that they vary widely in their polarity or magnetism. Both soil particles and herbicides can either be negatively or positively charged or neutral (no charge). Like charged particles tend to repel each other while oppositely charged particles tend to attract each other or bind together. Neutral particles are neither attracted nor repelled by other particles except through surface tension. Herbicides that have neutral polarity tend to move through the soil profile more readily.

Soil particles vary in the number of charge sites they may have. Sand particles have few charge sites, while clay particles and soils containing a lot of organic matter have many charge sites. Knowing the texture of the soil and the percentage of organic matter at a herbicide application site is important because they greatly affect the persistence of the herbicide in the soil and the ability of the herbicide to move in the soil. The type of soil particle not only determines its binding ability but also the pore space or water-holding capacity.

SOIL TEXTURE

Soil textures are categorized into three groups.

1. Sands and sandy loams are referred to as light- or coarse-textured soils.
2. Loams, silt loams, and clays are referred to as medium-textured soils.
3. Clay loams, silty clay loams, and clays are referred to as heavy- or fine-textured soils.

Soil texture can be determined by a soil test. Contact a local county extension office or a Natural Resources Conservation Service (NRCS) Office for information on how to collect soil samples. Detailed soil maps have been developed by the NRCS for most counties in Utah. Herbicide labels have recommended rates of application based on the soil texture.

The texture of soil basically is determined by the percentage of sand, silt, and clay in it. Sand particles are coarse and relatively large, and they have few charge sites. They have large pore openings between the particles that allow water to move down through the soil profile rapidly. The combined characteristics of few charge sites and large pore openings makes sandy soil the most permeable (the ability for water and herbicides to move with least resistance through the soil column). The risk of groundwater contamination is greatest in sandy soils.

Silt has more charge sites than sand and is finer in particle size; thus it is less porous than sand. Silty soils tend to hold more water and herbicide than do sandy soils, but not as much as clay soils.

Clay particles are fine with many charge sites. Water and herbicides tend to be bound up in clay soils. These soils act as a barrier to the flow of herbicides through the soil profile. Soils that are high in clay content require more soil-applied herbicide for weed control than do sandy soils.

Organic matter has many more negative charge sites than even the finest clay particles. In addition to the herbicide molecules tied up on the organic matter, there are also particles of water, sodium, calcium, and ammonia.

TEXTURE (CLAY)

Soils that are high in organic matter and clay content will hold a herbicide for a longer time than sandy soils. Herbicides are bound to the organic matter and clay particles and released so slowly that the chemical may not be effective as a herbicide. Herbicide persistence is greatest in soils with high organic matter and clay content.

HERBICIDE PERSISTENCE

The physical characteristics of a herbicide (polarity) and soil texture greatly affect the persistence of a herbicide in the soil. Other factors that affect herbicide persistence include the rate of application, microbial and chemical decomposition, solubility of a herbicide, and precipitation. These factors also affect how deep a herbicide will leach in soil.

Herbicides vary greatly in their ability to be soluble or uniformly dissolved in water. The greater the solubility of the chemical, the greater the potential for leaching deeper into the soil column. Soil microorganisms such as algae, fungi, and bacteria live in the soil and use organic matter as a food source. Organic herbicides are decomposed through this feeding process. Chemical decomposition of some herbicides occurs through chemical reactions such as oxidation, reduction, and hydrolysis. Annual rainfall affects how long a herbicide will persist in the soil, especially in the top one to four inches, where most weed seeds germinate. Herbicides tend to persist longer in dry areas.

HERBICIDE SELECTION

CROP KNOWLEDGE

A thorough knowledge of the crop where weeds are to be controlled is essential for weed control and crop protection. Selection of the proper herbicide, appropriate application rate, and the best timing for treatment depend on the crop being grown. A thorough knowledge of the herbicide labeled for use with a particular crop is also important. Herbicide labels provide detailed information for proper and safe use. A herbicide label provides the best guidelines for successful weed management.

CROP ROTATION

When selecting a herbicide, thought should be given to the crop rotation planned for the next year. A number of herbicides stay active in the soil for six months or more and will kill certain crops even when present in extremely low amounts. Application of a herbicide may limit which crop can be planted the following year. The following are two situations where crop rotation is limited. If atrazine is used in corn, a different crop cannot be planted for two years. If Banvel is used in grain or corn at fairly heavy application rates, especially in the fall, it would not be possible to rotate to broadleaf crops, such as beans, potatoes, or alfalfa the following spring. Crop rotation limitations are clearly stated on the labels of the herbicides registered for use in cropland. Herbicide selection is an important consideration when crop rotation is scheduled.

SURROUNDING VEGETATION

When choosing a herbicide to use for weed control, consider the vegetation that is close to the application site. Take precautions so that the that the herbicides used will not drift to nontarget areas. The contamination of nontarget vegetation by herbicides can occur three ways: by wind drift, physical movement, and volatilization.

Herbicide drift occurs when spray droplets are carried away from the application area by air movement. Smaller sized droplets have a greater potential for wind drift. Fog and mist applications present the greatest hazard. The distance a sprayed herbicide can drift depends on the speed of the wind, height of the nozzles above the ground, and size of the spray droplets.

Physical movement of a herbicide can occur when soil with herbicide particles bound to it is blown from the target site. This type of herbicide movement is more likely to happen when a herbicide application is made to bare ground. When applying any herbicide that is extremely active at low rates, such as the sulfonylurea herbicides, be careful around nontarget vegetation.

Volatilization or vaporization occurs from the evaporation of the herbicide after it hits the soil or plant surface. Certain herbicides such as the 2,4-D ester formulation and dicamba will vaporize during hot summer days. The movement of such vapor with wind currents may injure sensitive vegetation. If a herbicide volatilizes easily, precautions for use during hot weather will be stated on the label.

Applicators should follow the label directions concerning herbicide use and restrictions during hot weather. Recommendations found on herbicide labels for spray applications include:

- Mix and apply herbicide formulations having a low volatility,
- Apply herbicides using the lowest practical spray pressures,
- Apply herbicides using the largest practical spray droplet size,
- Apply herbicides when wind speed is low, and
- Do not apply herbicides during a tempera ture inversion (when air is coolest at ground level, gets warmer up to a certain height, and gets cooler from that point up).

III. AGRICULTURAL PLANT DISEASE MANAGEMENT

TOPIC **PAGE**

PLANT DISEASE MANAGEMENT

Pesticide applications, if economically and biologically justified, can reduce losses caused by plant pathogens (infectious agents) in field and vegetable crops, fruit trees, ornamentals and turf. Pesticides provide no benefit if applied to plants damaged by noninfectious agents such as nutrient imbalances, weather extremes, chemicals, and cultural practices. Successful control of plant pathogens through the use of pesticides is dependent upon the following conditions.

1. An infectious agent is causing the disease,
2. Application of a pesticide is justified,
3. An appropriate pesticide is selected, and
4. The rate, method, timing, and frequency of pesticide application are correct.

PLANT PATHOLOGY

The growth and yield of plants depend on the availability of nutrients and water in the soil where they grow and on favorable environmental factors such as temperature, moisture and light. Anything that affects the health of plants is likely to affect their growth and yield. Plants suffer from diseases that are similar in many ways to those affecting animals and humans.

A plant disease can cause disturbances that prevents the normal development of a plant and reduce its economic or aesthetic value. A disease interferes with the normal function of some part of the plant, resulting in reduced quality and/or yield. A list of major plant diseases appears in Appendix 3.

Diseases are caused by noninfectious agents that include environmental, nutritional and chemical imbalances, and by infectious agents including microorganisms and parasitic plants. Plant pathology is the study of four topics: (1) the noninfectious and infectious agents that cause diseases in plants, (2) mechanisms by which these agents produce diseases, (3) interactions between the disease causing agent and diseased plant, and (4) methods of preventing or managing the disease and its damage.

If a disease has not been previously identified or is not well known, then the diagnosis of a causal agent must involve four criteria:

1. The causal agent must be consistently associated with the disease,
2. The causal agent must be accurately identified or isolated in pure culture,
3. The symptoms found in the diseased plants must develop in healthy plants when they are inoculated with the pathogen, and
4. If caused by a biotic agent, the pathogen isolated in the second criteria must be isolated from plants inoculated in the third criteria.

NONINFECTIOUS AGENTS

Plant diseases may be caused by a change in the environment such as an excess or deficiency of some factor needed for growth or by some harmful substance in contact with the plant. Pathogens are not present in the noninfectious (abiotic) diseases and therefore cannot be transmitted from one plant to another. These diseases may occur during plant growth and handling, from germination to maturity; and in storage or processing. Symptoms of noninfectious agents are often confused with those caused by infectious (biotic) agents, and they range from slight to severe as plant tissue exhibits localized to general damage.

Extremes in temperature, moisture, or light are often unfavorable for plant growth. Nutritional deficiencies and excesses cause disease like problems that must be correctly identified if they are to be corrected. Chemically induced plant disease results from improper soil pH, improper use of fertilizers and pesticides, chemical spills and runoff, and air pollution. Cultural practices may compact soil or mechanically wound plant tissue, creating unfavorable conditions for plant growth. These conditions may predispose plants to infection by biotic agents.

Plants require a certain balance of nutrients or mineral elements for normal growth. Nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur are needed in large amounts and are called major elements. Iron, chlorine, molybdenum, manganese, copper, zinc, and boron are usually needed in very small amounts and are called trace or minor elements. When one or more of these nutrients are deficient or excessive, plants become diseased and exhibit various symptoms that may appear on the roots, stems, leaves, flowers, fruits, and/or seeds.

These symptoms include:
1. Reduction of growth and yield,
2. Tissue discoloration and burning (colors of white, light green, yellow to brown),
3. Curling and distortion of leaves and other plant structures, and
4. Wilting, and/or death.

Nutrient imbalances can be identified by analysis of soil and tissue samples at a qualified soil-analysis laboratory. Based on the test results, fertilization programs can be devised to prevent or correct the nutritional problem.

Table 1. Nutrient Deficiencies in Plants

Nutrient	Symptoms
Nitrogen	Light green color, lower leaves turn yellow to brown, poor growth
Phosphorus	Bluish-green leaves, lower leaves light bronze
Potassium	Yellowing of older leaves and brown tips, scorched and spotted margins, dieback if severe
Magnesium	Older leaves affected first, mottled or yellowed, then reddish, tips and margins of leaves cup upward, drop
Manganese	Yellow leaves, major veins remain green and checked
Iron	Young leaves are yellow, major and minor veins green, brown spots
Zinc	Interveinal yellowing, brown, short internodes.

Most plants will not grow well in acid (pH less than seven) or alkaline (pH greater than seven) soils when the levels are extreme. In acid soils, mineral salts are more soluble and so concentrated that they are toxic to plants or interfere with absorption of other necessary elements. Symptoms of mineral deficiency then develop. Excessive amounts of certain salts raise the soil pH and cause alkali injury such as burning (tan to brown discoloration) of leaf edges. In alkaline soils, minor elements like iron and zinc are not available to the plant resulting in severe growth reduction. Soil tests can help identify these types of problems and provide guidelines for their management with future crops.

Weather extremes can damage plants at various stages during their development and maturity. Low temperature will injure plants by causing ice formation between and/or within cells that, in turn, injures membranes and other cell components. Late spring and early fall frosts damage and kill tender plants, buds, leaves, flowers, fruits, and seeds. Damaged tissue wilts, turns brown to black, and dies. Spring frost damage can usually be avoided by planting on recommended dates. Proper shading, covering, mulching, irrigating, fertilizing, and heating help reduce the damage if cold temperatures are not too extreme.

Leaf scald or sunburn occurs during periods of high temperature following periods of rapid plant growth, especially after rainy and cloudy weather. Large, irregular, water soaked, or dead areas may form on sun exposed portions of succulent leaves or fleshy fruits and vegetables, including apples, tomatoes, onions, and potatoes. Excessive light, drought, high winds, and the low relative humidity that usually accompanies high temperatures all intensify hot weather injury. Little can be done to decrease the effect of these damaging conditions. Reducing soil compaction, crop irrigation, and the planting of varieties resistant to heat stress are the best ways to reduce high temperature damage.

Moisture extremes can damage any type of plant. Too much or too little water will cause injury. During the sensitive stages of plant growth, flowering and fruit production, the correct amount of moisture is important. The first symptom of water shortage in plants is wilting of tissue that may recover during the night. If the water stress continues, plants become dwarfed and stunted. Leaves yellow or redden, begin to die along the tips and margins, and finally drop off.

Other plant parts can be similarly affected, and maturity may even be delayed. Plants may suffer injury when soils become flooded, are water logged, or poorly drained. The plants cannot get enough oxygen for normal growth or they become infected by soil-borne pathogens. Flooding symptoms can include wilting, yellowing, stunting, and death..

Phytotoxic chemicals can damage plants, especially when used improperly. Air pollution from machinery and industry can drift long distances and damage sensitive tissue. Such damage will cause bronze to brown flecking of leaf tissue and tips. One of the common causes of chemical damage is a herbicide applied at a rate too high for soil conditions. This is especially true if wet and cool conditions occur for prolonged periods after planting and/or if soils are compacted and poorly drained. Sensitive roots and growing points may be exposed to toxic levels of the pesticide, solvent, diluent, or carrier. Temperature and humidity affect the severity of the damage, which may include stunting of roots and plants, distortion or discoloration of leaves and other plant organs, yield reduction, and tissue and plant death.

The most effective way to prevent chemical injury is to apply the correct pesticides at the appropriate rates and use methods to reduce drift and contamination of soil and water. Management recommendations also include following an appropriate crop rotation and planting date, planting less sensitive varieties, and improving soil conditions and drainage.

INFECTIOUS AGENTS

Diseases caused by infectious agents (plant pathogens) are characterized by their presence on or within plants. The detection and identification of plant pathogens may be accomplished by examination with the naked eye, with a magnifying lens, by microscopic viewing, and/or by laboratory isolation. If a pathogen is not located on the surface of the diseased plant, then additional symptoms and presence of the pathogen may be found inside the plant. Examinations should be done at the margins of affected tissue, in or near vascular tissue, or at the base of the plant such as in its roots.

The general classes of plant infectious agents that cause plant diseases are parasitic plants (dodder, for example), nematodes (alfalfa-stem nematode), fungi (white mold of beans), bacteria (black leg of potato), phytoplasmas (pear decline), and viruses and viroids (barley yellow dwarf virus). Quite often, a plant is attacked by two or more pathogens, often in combination with a noninfectious agent that may cause additional stress or predisposition to infectious agents.

PARASITIC PLANTS

Parasitic plants are higher plants that reproduce by seed. Most of the parasitic plants have modified root-like structures that attach to plant tissue to get nutrients and water, thereby weakening the host and reducing its productivity. Examples of parasitic plants include dodder, and leafy and dwarf mistletoes. Dodder can affect many crops, including alfalfa, onions, and potatoes.

Control recommendations include using clean seed and equipment to prevent parasite introduction, crop rotation, restricting movement of livestock between fields, and herbicide applications.

NEMATODES

Nematodes are small (one-fiftieth to one-fourth-inch long), eel-like worms that feed on plants by means of a miniature hypodermic-like structure called a stylet, which is used to suck liquid nutrients out of plant cells.

Females of some species become swollen at maturity and have pear shaped or oval bodies. Nematodes reproduce by laying eggs that hatch as larvae or juveniles. The larvae develop through a series of four molts, where the outer skin is shed, until they become adults. Such nematodes can complete their life cycle in less than 30 days. Some nematode species damage plants primarily by feeding on the outside (ectoparasites), while others (endoparasites) enter and feed from within the plant tissue such as in roots. Nematodes cause damage to plants by injuring cells, removing cell contents, and/or changing normal plant growth processes.

Symptoms of nematode infestation include poor growth, reduced yield and quality, stunting, yellowing, and wilting of plants that cannot get enough water and nutrients. Nematodes may also interact with other pathogens (synergism) to cause more damage than either organism individually. Nematodes can act as wounding agents (predispose roots to soil borne fungal and bacterial pathogens), host modifiers (enzyme and hormone changes in plant tissue), and vectors (of viruses, for example).

Control recommendations include crop rotation, using clean equipment, irrigating with noncontaminated water, biological agents, resistant varieties, and pesticide (nematicide and fumigant) applications. Nematodes are a minor problem in Utah, except for the alfalfa stem nematode.

FUNGI

Fungi (singular: fungus) are small, threadlike organisms composed of tiny filaments called hyphae. Individual hyphae are composed of strands of simple microscopic cells. A mass of branched and intertwined hyphae is collectively called mycelium. Some fungi grow inside plant tissue or organic debris and cannot be seen unless magnified. Other fungi produce visible mildew, molds, and mushrooms. Most fungi produce microscopic spores, which are often spread between plants by wind, water, soil, machinery, animals, or humans.

Spores land on a plant and germinate by producing a germ tube. Hyphae then develop and penetrate the plant surface directly or through natural openings (stomates) and wounds. Fungi damage plants by producing toxins, enzymes, or growth regulating substances that alter or destroy plant tissue. Diseases include leaf spot, blight, canker, dieback, root rot, damping off, basal stem rot, soft and dry rots, scab, stunting, galls, wilt, rust, mold, and mildew. About 8,000 species of fungi can cause plant diseases and all plants can be attacked by some kind of fungus. Some fungi can grow and multiply only on a living host, while others grow and multiply on dead organic matter as well as on living plants.

Control recommendations include crop rotation, sanitation of previously infected debris, selecting clean seed and transplants, using clean water and equipment, scheduling planting to reduce exposure during favorable weather, utilizing biological agents, selecting resistant varieties, and applying fungicides.

BACTERIA

Bacteria (singular: bacterium) are microscopic, single celled organisms that possess rigid cell walls, contain cytoplasm, have no roots, stems, or leaves, and contain no chlorophyll. Some bacteria have long, slender, hair like coiled appendages called flagella that propel the organism through water. Bacteria reproduce by a process called binary fission in that one cell divides into two cells (possibly every 20 to 30 minutes). Thousands of bacteria can occupy a single drop of water. The rapid multiplication of bacteria and production of toxins and enzymes that alter or destroy plant tissue contribute to the damage caused by bacteria. They enter plants through wounds or natural openings. Symptoms include leaf spots and blights, soft rots, wilts, scabs, cankers, and overgrowths.

Control recommendations include crop rotation, sanitation, selecting clean seed and transplants, using clean water and equipment, utilizing biological agents, selecting resistant varieties, and applying pesticide (antibiotics, bactericides).

PHYTOPLASMAS

Phytoplasmas are small, single-celled organisms that occur inside plant phloem cells. Phytoplasmas do not have rigid cell walls. They assume various shapes and are enclosed by a triple layered cell membrane. Many diseases caused by phytoplasmas, were originally believed to be caused by viruses (yellows). Phytoplasmas are spread between plants by vectors such as leafhoppers. Phytoplasmas can also be spread in infected plant parts. Symptoms include stunting, proliferation of shoots and roots, yellowing or reddening of foliage, abnormal flowers, and eventual decline and death of the plant.

Control recommendations include crop rotation, weed control of alternate hosts, sanitation of previously infected debris, transplanting clean stock, insect-vector control, resistant variety selection, and pesticide treatment (tetracycline injection) of infected planting stock for phytoplasma diseases.

VIRUSES AND VIROIDS

Viruses and viroids are very small particles composed of nucleic acid and protein. They can be seen only under an electron microscope. Viruses that infect plants are generally spherical or rod-shaped. Nucleic acid (usually ribonucleic acid or RNA) composes the center of virus particles and is surrounded by a protein coat. Viruses cause diseases in plants by diverting energy and structural components, normally used for plant growth, into reproductive processes for the virus. Viruses are spread between plants by insect vectors (aphids, leafhoppers, thrips, whiteflies), nematode vectors, infected plant parts. man, and machinery. Viroids are smaller than viruses. They act like viruses, but the infectious particle is simply a strand of RNA and contains no protein. Symptoms of viruses and viroids include stunting, local lesions, ring spots, mosaics, yellowing, pitting, and distortions of leaves and other plant parts.

Control recommendations include crop rotation, weed control of alternate hosts, sanitation of previously infected debris, using clean transplants and seed, insect-vector control, resistant variety selection, and heat-treatment of planting material.

RECOGNIZING PLANT DISEASES

Plant diseases are initially diagnosed or suspected by the presence of characteristic signs and/or symptoms that are associated with a particular disease or disease complex. Examples are visible masses of hyphae and spores such as mildew, mold, rust, and smut, or other structures that might include white-mold sclerotia.

Symptoms of disease may appear as infection or injury of the plant and may include stunting, dead or rotten spots on plant parts, discoloration, swelling, blight, wilting, and water soaking. A list of Utah's major plant diseases appears in Appendix 3.

NECROTIC SYMPTOMS

1. **Leaf spots** - localized lesions on host leaves consisting of dead and collapsed cells; lesion color may range from white to yellow to black, depending on the disease; the dead center of a lesion may drop out, leaving a shot hole; chlorosis refers to a yellow-to-green color; necrosis usually refers to dead tissue with a white, tan, brown, or black color
2. **Blight** (scorch, firing, blast, scald) - general and rapid browning of plant parts resulting in their death
3. **Canker** (pitting) - a localized wound or necrotic lesion often sunken beneath the surface of the stem or tree trunk
4. **Dieback** - extensive necrosis of plant parts beginning at their tips and advancing toward their bases
5. **Root rot** - disintegration or decay of part or all of the root system
6. **Damping off** - rapid death and collapse of very young seedlings before or after emergence
7. **Basal stem rot** - disintegration of the lower part of the plant
8. **Soft rots** (leak) **and dry rots** - a wet or dry disintegration of plant parts; may include localized soft rotting or water soaking of tissue
9. **Scab** - localized, slightly raised or sunken, cracked lesions usually on the fruit
10. **Decline and stunting** - poor plant growth; leaves are often small, brittle, and yellow or red; some defoliation and dieback may be present

DISTORTION SYMPTOMS

11. **Clubroot** - enlarged roots that appear like clubs or spindles
12. **Galls** - usually small plant portions such as root hairs become enlarged
13. **Warts** - wart-like protuberances on tubers and stems
14. **Witches'-broom** - profuse upward branching of plant parts
15. **Leaf curl** - distortion, thickening and curling of leaves

OTHER SYMPTOMS

16. **Wilt** (flagging) - usually a generalized but secondary symptom where leaves or shoots lose their turgidity and droop because of a disturbance in the vascular system of the root or stem
17. **Rust** - small lesions on leaves or other plant parts containing masses of fungus spores that are white, orange, red, brown, or black
18. **Mildew** - chlorotic or necrotic areas on plant parts usually covered with white mycelium and spores of a fungus
19. **Mold** - any profuse or woolly fungus growth on damp or decaying matter or on surfaces of host tissue

DEVELOPMENT OF PLANT DISEASES

For a plant disease to exist, a pathogen, susceptible host plant, and favorable environment must be present and interact over a period of time. Disease development in cultivated plants is also greatly influenced by human input. There are many possible combinations of time, pathogen, host, and environment.

The term "**disease cycle**" is used to describe the relationship of a pathogen to its host in an environment and the development of a disease over time. It involves survival of the pathogen during periods that are not favorable for disease development, dispersal of the pathogen to its host, growth of the pathogen on or in plants, development of disease symptoms, and, finally, pathogen survival to complete the cycle. The study of survival and spread of pathogens and disease development in a population of plants over time is called **epidemiology**.

There are many interactions of temperature, moisture, wind, light, plant nutrition, soil type, soil pH, and cultural practices that contribute to disease development. Not all pathogens and the diseases they cause respond similarly to the same set of environmental conditions. Many diseases develop at temperatures most favorable for pathogen development but unsuitable for the host. The occurrence of disease, especially foliar problems in semi arid areas, is often closely correlated with the amount and distribution of irrigation or rainfall. Nutritional imbalances, either excesses or deficiencies, may stress root systems or provide excess foliage that favors specific pathogens. Soil compaction, chemical damage, and timing of various agronomic practices such as planting, cultivating, irrigating, or harvesting can increase or reduce various pathogens and their disease development.

Many pathogens can survive in the absence of a susceptible host during conditions that are unfavorable for disease development. Pathogens of annual plants may survive from one growing season to the next in alternate hosts, plant debris, seed, or soil. Many pathogens of perennial plants survive in infected tissue of the host plant or in propagating material. When conditions are favorable, these pathogens begin to grow and spread to susceptible plants or tissue.

Pathogens are usually spread by wind, water, soil, in plant parts, or by vectors such as insects or humans. Some bacterial cells and fungal spores can be blown hundreds of miles, while other pathogen structures are dispersed only a few inches or feet from their point of production or survival. Winds strong enough to blow dust particles have enough power to carry insects, nematode eggs, and billions of invisible pathogens capable of causing disease outbreaks throughout and between fields and regions. Rainwater and runoff are also major transporters of pathogens.

The process whereby a pathogen (inoculum) comes in contact with the host is called **inoculation**. For disease to develop, the pathogen must penetrate the host, invade tissue, grow, and become established within the infected host. The time between inoculation and symptom development is known as the **incubation period**, which may vary from a few days to weeks depending on the host, pathogen, and environment. Successful inoculation and incubation result in infection.

As a particular pathogen grows in a host plant, symptoms begin to appear. Before symptoms develop, many biochemical and physiological changes have usually occurred. Visible symptoms are responses of the plant to disease processes that have been occurring since inoculation.

Some diseases, including many of the root rots, have only one cycle during a growing season. Other diseases, especially ones that occur in aerial parts of the host, develop secondary or repeating disease cycles during a growing season. Recurrent crops of spores or bacterial cells, maturing every seven to 14 days, provide inoculum to infect nearby healthy tissue and plants.

Such diseases develop quickly and may cause severe damage over a short period of time (epidemic).

The disease cycle is completed when a pathogen reaches the survival stage. Many pathogens produce specialized structures such as sclerotia and resistant spores that enable the pathogen to resist freezing, drying, or other adverse conditions until the disease cycle can be completed once again.

PLANT DISEASE MANAGEMENT

Plant diseases are most often controlled with cultural techniques that include practices such as planting date, planting sites, irrigation management, crop rotation and proper agronomic practices. The most effective and economical way to control diseases is through the use of resistant cultivars. Plant diseases are generally managed using a preventive strategy rather than implementing control after the disease is present. Most plant disease control chemicals are not effective in eradicating existing disease and must be used before the disease is present. For these reasons only a small number of pesticides are used to control plant disease under normal conditions.

Epidemiology enables plant protection specialists to study pathogens and identify effective methods of controlling or managing them and their potential to cause losses due to disease. Control methods are classified as **regulatory, cultural, biological, physical,** and **chemical.**

Regulatory controls try to exclude a pathogen from a host or from a certain geographic area. Most cultural controls help plants avoid contact with a pathogen and eradicate or reduce the amount of a pathogen (inoculum) in a plant, field, or area. Biological and some cultural controls improve host resistance or favor microorganisms antagonistic to the pathogen.

Physical and chemical controls protect plants from pathogen inoculum that may arrive and cure or reduce infection that is already in progress. Individual control methods are usually integrated to provide a more comprehensive and effective strategy for management of a disease, a disease complex, and multiple pests that often threaten an individual crop during its development.

Eradication and reduction of pathogen inoculum can be achieved by regulatory controls such as quarantines and inspections. Disease-resistant varieties and pathogen-free seed and propagating material are important and effective tools. Host eradication, crop rotation, sanitation, planting date, improving plant growing conditions, creating conditions unfavorable to pathogens, mulching, irrigation method and timing, and cultivation methods represent cultural practices that can be altered to more effectively manage many plant pathogens.

Some physical methods such as soil sterilization, heat treatment, refrigeration, and radiation, chemical methods such as soil fumigation and seed treatment, and biological methods such as antagonistic organisms and trap crops can also reduce inoculum and the potential for disease epidemics to occur.

Direct protection against pathogen infection and development is achieved using chemical compounds that are toxic to the pathogen. Such chemicals limit growth and multiplication, inhibit pathogen germination, or are lethal to the pathogen. Some chemicals are toxic to all or most kinds of pathogens, while others only affect one or a few pathogens. Depending on the kind of pathogens they affect, the chemicals are called fungicides, bactericides, nematicides, or herbicides. Insecticides are used to control the insect vectors of some pathogens.

Some of the newer fungicides, such as sterile inhibitors, have a therapeutic (eradicant) action, and several are absorbed and systemically translocated by the plant (systemics). Fungicides may be applied to the soil (fumigation, soil furrow treatments), seed, irrigation system, foliage, and other plant parts (dust, liquid treatments).

Soil fumigants and treatments reduce the amount of initial inoculum present before planting a crop susceptible to a slow-moving disease such as root rot or even nematodes. Fumigants must be applied to well cultivated soil with low organic matter, in the presence of adequate moisture, and while temperatures are above 50 degrees F. Treated sites must remain fallow for several days to weeks so that the fumigant volatilizes completely and is no longer toxic to seed and seedlings.

Seed treatments protect seedlings against infection by soil-borne pathogens during the first few days of germination and emergence. Most of these chemicals act only at the surfaces of seed and in the nearby soil. However, some chemicals may penetrate to eradicate pathogens within the seed and seedling.

Foliar treatments provide a protective layer against and exclude pathogens (protectants) or eradicate (systemics) pathogens from treated plant parts. Correct timing, thorough application, and choice of the proper chemical are essential for effective and economical control. Because many fungicides and bactericides are protectant in their action, it is important that they be on the plant surface before the pathogen arrives or germinates, enters the host, and establishes itself. Since many pesticides are effective only on contact with the pathogen, and pathogens are not generally mobile, it is important that the whole surface of the plant be covered with the chemical.

Fungicides and Bactericides Used In Utah

1. Antibiotics (streptomycin, tetracycline)
2. Coppers (cupric hydroxide, copper oxychloride, copper ammonium carbonate)
3. Inorganic and organic sulfurs
4. Dithiocarbamates (thiram, maneb, ancozeb, metam-sodium)
5. Aromatics (pentachloronitrobenzene, dichloran, chlorothalonil)
6. Heterocyclic compounds (captan, captafol, iprodione, vinclozolin)
7. Acylalanine (metalaxyl)
8. Benzyimidazoles (benomyl, thiabendazole)
9. Oxathiin (carboxin)
10. Organic phosphate (fosetyl Al)
11. Pyrimidine (fenarimol)
12. Triazoles (myclobutanil, triadimefon, propiconazole)
13. Other systemics (chloroneb, ethazol, imazalil, thiophanate-methyl)

Nematicides Used In Utah:

1. Halogenated hydrocarbons methylbromide)
2. Organophosphates (disulfoton, fenamiphos)
3. Isothiocyanates (vorlex)
4. Carbamates (aldicarb, carbofuran, oxamyl)
5. Chloropicrin

A list of major plant diseases in Utah appears in Appendix 3.

IV. WORKER PROTECTION STANDARD

The U.S. Environmental Protection Agency's Worker Protection Standard (WPS), as revised in 1992, must be complied with when pesticides are used on agricultural establishments, including farms, forests, nurseries, and greenhouses, for the commercial or research production of agricultural plants. The WPS requires employers to provide agricultural workers and pesticide handlers with protections against possible harm from pesticides. Persons who must comply with these instructions include owners or operators of agricultural establishments and owners or operators of commercial businesses that are hired to apply pesticides on the agricultural establishment or to perform crop-advising tasks on such establishments. Family members who work on an agricultural or commercial pesticide establishment are considered employees in some situations.

WPS requirements for employers include:

- **Displaying information** about pesticide safety, emergency procedures, and recent pesticide applications on agricultural sites.
- **Training** workers and handlers about pesticide safety.
- Helping employees get **medical assistance** in case of a pesticide related emergency.
- Providing **decontamination sites** to wash pesticide residues off hands and body.
- Compliance with **restricted entry intervals** (REI)- the time after a pesticide application when workers may not enter the area.
- **Notifying** workers through posted and/or oral warnings about areas where pesticide applications are taking place and areas where REI are in effect.
- Allowing only **trained and equipped workers** to be present during a pesticide application.
- Providing **personal protective equipment** (PPE) for pesticide handlers and also for workers who enter pesticide treated areas before expiration of the REI.
- **Protecting pesticide handlers** by giving them safety instructions about the correct use of pesticide application equipment and PPE and monitoring workers and handlers in hazardous situations.

One of the provisions of the WPS is the requirement that employers provide handlers and workers with ample water, soap, and single use towels for washing and decontamination from pesticides and that emergency transportation be made available in the event of a pesticide poisoning or injury. The WPS also establishes REI and the requirements for PPE. PPE requirements are specified for all pesticides used on farms and in forests, greenhouses, and nurseries. Some pesticide products already carried REI and PPE directions. This rule raised the level of protection and requirements for all pesticide products.

Other major provisions require that employers inform workers and handlers about pesticide hazards through safety training. Handlers must have easy access to pesticide label safety information and a listing of treatments site must be centrally located at the agricultural facility. Handlers are prohibited from applying a pesticide in a way that could expose workers or other people.

References: ***The Worker Protection Standard for Agricultural Pesticides How to Comply: What Employers Need to Know***. Web site <www.usda.gov/oce/oce/labor-affairs/wpspage.htm>.

V. PROTECTING GROUNDWATER AND ENDANGERED SPECIES

INTRODUCTION

Federal and state efforts to protect groundwater and endangered species have resulted in special requirements and restrictions for pesticide handlers and applicators. Pesticides that are incorrectly or accidentally released into the environment can pose a threat to groundwater and endangered species. Whether pesticides are applied indoors or outdoors, in an urban area or in a rural area, the endangered species and groundwater must be protected and state and federal agencies rigidly enforce this requirement.

The need for special action by the pesticide handler/applicator depends on site location. Groundwater contamination is of special concern in release sites where groundwater is close to the surface or where the soil type or the geology allows contaminants to reach groundwater easily. In the case of endangered species, special action is normally required in locations where the species currently live or in locations where species are being reintroduced. The product labeling is the best source to determine if pesticide use is subject to groundwater or endangered species limitations.

The U.S. Environmental Protection Agency (EPA) establishes the specific limitations or instructions for pesticide users in locations where groundwater or endangered species are most at risk. These limitations and instructions may be too detailed for inclusion in pesticide labeling. In such cases the labeling will direct the applicator or handler to another source for instructions and restrictions. The legal responsibility for following instructions that are distributed separately is the same as it is for instructions that appear on the pesticide labeling.

PROTECTING GROUNDWATER

Groundwater is water located beneath the earth s surface. Many people think that groundwater occurs in vast underground lakes, rivers, or streams. Usually, however, it is located in rock and soil. It moves very slowly through irregular spaces within otherwise solid rock or seeps between particles of sand, clay, and gravel. An exception is in limestone areas, where groundwater may flow through large underground channels or caverns. Surface water may move several feet in a second or a minute. Groundwater may move only a few feet in a month or a year. If the groundwater is capable of providing significant quantities of water to a well or spring, it is called an aquifer. Pesticide contamination of aquifers is very troubling, because these are sources of drinking, washing, and irrigation water.

Utah has implemented a comprehensive and coordinated approach to protect groundwater from pesticide contamination. Formulation of the Utah Groundwater and Pesticide State Management Plan is a cooperative effort between federal, state, private agencies, producers, and user groups. It provides a basis for continuing future efforts to protect groundwater from contamination whenever possible. Furthermore, this plan provides agencies with direction for management policies, regulations, enforcement, and implementation of groundwater strategies.

Utah recognizes that the responsible and wise use of pesticides can have a positive economic impact, yield a higher quality of life, enhance outdoor activities, and give relief from annoying pests. The EPA has authorized the Utah Department of Agriculture and Food (UDAF) to enforce the protection of groundwater from pesticides.

The UDAF, in concert with cooperating agencies and entities, demands strict compliance with all pesticide labels, handling procedures, and usage to protect groundwater in the state.

Prevention of groundwater contamination is important, because once the water is polluted, it is very difficult and costly to correct the damage and in some instances impossible. City and urban areas contribute to pollution because water runoff can contain pesticides. Shallow aquifers or water tables are more susceptible to contamination than deeper aquifers or water tables. Sandy soils allow more pollution than clay or organic soils, because clays and organic matter adsorb many of the contaminants. For more information about what groundwater is and where it comes from, read the study manual ***Applying Pesticides Correctly: A Guide for Private and Commercial Applicators.***

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), as amended, establishes a policy for determining the acceptability of a pesticide use or the continuation of that use, according to a risk/benefit assessment. As long as benefits outweigh adverse effects, the EPA can continue to register the pesticide. Although the intent of a pesticide application is to apply the pesticide to the target or pest, part of the pesticide will fall on the area around the target or pest. Rain or irrigation water then can pick up the part that is not degraded or broken down and carry it to the groundwater via leaching.

There are many factors that influence the amount of pesticide contamination that can get into groundwater. The major factors are the soil type, soil moisture, persistence in soil, placement of the pesticide, frequency of application, pesticide concentration and formulation, pesticide water solubility, and precipitation. Each of these factors will influence the amount of pesticide that can penetrate the soil surface, leave the root zone, and percolate into groundwater.

Although some pesticides may have a high adsorption quality, when they are applied to sandy soil, they may still migrate to the water table because there are few clay particles or little organic matter to bind them. The management and use of pesticides is up to the individual applicator and/or landowner as to whether safe practices are used. Groundwater is a very valuable resource and it must be protected form pesticide contamination.

PROTECTING ENDANGERED SPECIES

The Federal Endangered Species Act lists the three classifications as endangered, threatened, and experimental. Endangered has the highest level of protection. The phrase “endangered species” is used when referring to these classifications. This Act was passed by Congress to protect certain plants and wildlife that are in danger of becoming extinct. A portion of this Act requires EPA to ensure that these species are protected from pesticides.

EPA's goal is to remove or reduce the threat to endangered species that pesticides pose. Achieving this goal is a portion of the larger continuing effort to protect species at risk. Normally these restrictions apply to the habitat or range currently occupied by the species at risk. Occasionally the restrictions apply where endangered species are being reintroduced into a habitat previously occupied.

Habitats are the areas of land, water, and air space that an endangered species needs for survival. Such areas include breeding sites, sources of food, cover, and shelter, and the surrounding territory that provides space for normal population growth and behavior.

Utah's endangered species plan is a cooperative effort between federal, state, private agencies, producers, and user groups. This plan provides agency direction for regulations, enforcement, management policies, and implementation of threatened and endangered species protection strategies.

EPA has launched a major project known as Endangered Species Labeling (ESL). The goal is to remove or reduce the threat to endangered species from pesticides. EPA has the responsibility to protect wildlife and the environment against hazards posed by pesticides. The ESL program is administered by the U.S. Fish and Wildlife Service (FWS) in the U.S. Department of Interior. The FWS reports to EPA concerning endangered species. EPA and FWS work cooperatively to ensure that there is consistency in the pesticide restriction information provided to agencies and pesticide users.

The UDAF acts under the direction and authority of EPA to carry out the ESL project as it relates to the use of pesticides in Utah. Many states have web sites with maps designating the habitat boundaries and listings of endangered plants and wildlife. Utah's site is www.utahcdc.usu.edu.

References: ***Applying Pesticides Correctly: A Guide for Private and Commercial Applicators.*** Also, Endangered Species Act of 1973, with amendments through 1996 <www.house.gov/resources/105cong/reports/105_c/esaidx.htm>.

VI. CALIBRATION INFORMATION

Unit Conversion

One acre = 43,560 square feet	Example: ½ acre = 21,780 square feet
One mile = 5,280 feet	Example: ¼ mile = 1320 feet
One gallon = 128 fluid ounces	Example: ½ gallon = 64 fluid ounces
One quart = 2 pints = 4 cups = 32 fluid ounces	Example: 2 quarts = 64 fluid ounces
One pint = 2 cups = 16 fluid ounces	Example: ½ pint = 1 cup = 8 fluid ounces
One tablespoon = 3 teaspoons = 0.5 fluid ounces	Example: 2 tablespoons = 1 fluid ounce
One pound = 16 ounces	Example: ¼ pound = 4 ounces
One gallon = 231 cubic inches	Example: 2 gallons = 462 cubic inches

Weights

1 ounce	= 28.35 grams
16 ounces	= 1 pound = 453.59 grams
1 gallon water	= 8.34 pounds = 3.785 liters = 3.78 kilograms

Liquid Measures

1 fluid ounce	= 2 tablespoons = 29.573 milliliters
16 fluid ounces	= 1 pint = 0.473 liters
2 pints	= 1 quart = 0.946 liters
8 pints	= 4 quarts = 1 gallon = 3.785 liters

Length

1 foot	= 30.48 centimeters
3 feet	= 1 yard = 0.9144 meters
16 1/2 feet	= 1 rod = 5.029 meters
5280 feet	= 320 rods = 1 mile = 1.6 kilometers

Area

1 square foot	= 929.03 square centimeters
9 square feet	= 1 square yard = 0.836 square meters
43560 square feet	= 160 square rods = 1 acre = 0.405 hectares

Speed

1.466 feet per second	= 88 feet per minute = 1 mph = 1.6 kilometers per hour (kph)

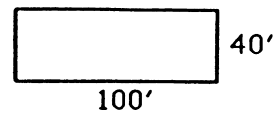
Volume

27 cubic feet	= 1 cubic yard = 0.765 cubic meters
1 cubic foot	= 7.5 gallons = 28.317 cubic decimeters

Area and Volume Calculations:

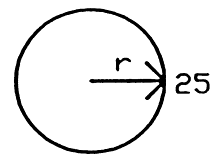
Area of Rectangular or Square Shape

The area of a rectangle is found by multiplying the length (L) times the width (W).
(Length) x (Width) = Area
Example: (100 feet) x (40 feet) = 4000 square feet



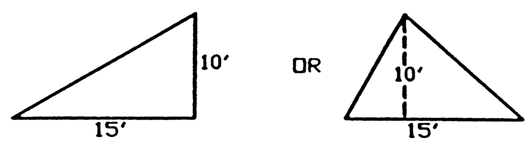
Area of Circle

The area of a circle is the radius (radius = one-half the diameter), times the radius, times 3.14.
(radius) x (radius) x (3.14) = Area
Example: (25 feet) x (25 feet) x (3.14) = 1962.5 square feet



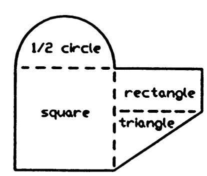
Area of Triangular Shape

To find the area of a triangle, multiply ½ times the width of the triangle's base, times the height of the triangle.
(½) x (base width) x (height) = Area
Example: (½) x (15 feet) x (10 feet) = 75 square feet

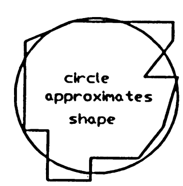


Area of Irregularly Shape

Irregularly shaped sites can often be reduced to a combination of rectangles, circles, and triangles. Calculate the area of each shape and add the values together to obtain the total area.
Example: Calculate the area of the rectangle, triangle,
square, and one-half of a circle.



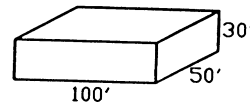
Another method is to convert the site into a circle. From a center point, measure the distance to the edge of the area in 10 or more increments. Average these measurements to find the radius, then calculate the area using the formula for a circle.
Example: Approximate the area by calculating
the area of a similarly sized circle.



Volume of Cube and Box Shapes

The volume of a cube or box is found by multiplying the length, times the width, times the height.
(Length) x (Width) x (Height) = Volume

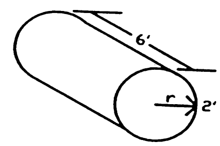
Example: (100 feet) x (50 feet) x (30 feet) = 150,000 cubic feet



Volume of Cylindrical Shapes

The volume of a cylinder is found by calculating the area of the round end (see formula for circle) and multiplying this area times the length or height.

Example: (radius) x (radius) x (3.14) = Area of Circle
(Area of Circle) x (Length) = Volume of Cylinder
(2 feet) x (2 feet) x (3.14) x (6 feet) = 75.36 cubic feet



Sprayer Calibration Formulas

To Calculate Travel Speed in Miles Per Hour:

The travel speed of a sprayer is determined by measuring the time (seconds) required to travel a know distance (such as 200 feet). Insert the values in the following formula to determine the miles per hour.

$$\frac{\text{Distance in Feet x 60}}{\text{Time in Seconds x 88}} = \text{Miles Per Hour}$$

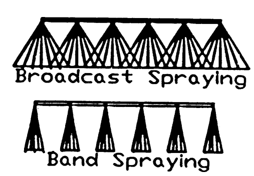
Example: $$\frac{\text{(200 feet) x (60)}}{\text{(30 seconds) x (88)}} = \frac{12{,}000}{2640} = 4.55 \text{ mph}$$

To Calculate the Gallons Per Minute Applied During Broadcast Spraying:

The application rate in gallons per minute (GPM) for each nozzle is calculated by multiplying the gallons per acre (GPA), times the miles per hour (MPH), times the nozzle spacing in inches (W); then dividing the answer by 5940. For small adjustments in GPM sprayed, operating pressure is changed. For large adjustments in GPM sprayed, travel speed (miles per hour) is changed or nozzle size is changed.

$$\frac{\text{GPA x MPH x W}}{5940} = \text{GPM}$$

Example: $$\frac{\text{(12 GPA) x (4.5 MPH) x (24")}}{5940} = \frac{1296}{5940} = 0.22 \text{ GPM}$$



To Calculate the Gallons Per Minute Applied During Band Spraying:

Broadcast spraying applies chemicals to the entire area. Band spraying reduces the amount of area and chemicals sprayed per acre. To use the above formulas for band sprayer applications, use the band width (measured in inches) rather than nozzle spacing for the "W" value.

Pesticide Mixing

Terminology:

The ***active ingredients*** of a pesticide are the chemicals in a formulation that control the target pests. The ***formulation*** is the pesticide product as sold, usually a mixture of concentrated active ingredients and an inert material. Restricted use pesticides are purchased in formulations requiring ***dilution prior to application***. Formulations are diluted with inert substances such as water. The ***percentage of active ingredients*** in a pesticide formulation directly affects dilution and application rates. Given two pesticides, A = 50% active ingredients, B = 100% active ingredients; twice as much pesticide A formulation is required to equal pesticide B formulation.

To Determine Total Amount of Pesticide Formulation Required Per Tank:

To calculate the total amount of pesticide formulation needed per spray tank, multiply the recommended dilution, ounces/pints/cups/teaspoons/tablespoons/etc. of pesticide per gallon of liquid, times the total number of gallons to be mixed in the sprayer. A full or partial tank of pesticide spray may be mixed.
(Dilution Per Gallon) x (Number of Gallons Mixed) = Required Amount of Pesticide Formulation Example: (3 ounces per gallon) x (75 gallons) = 225 ounces

Note: 1 gallon = 128 ounces; through unit conversion 225 ounces = 1.76 gallons

To Calculate the Amount of Pesticide Formulation Sprayed Per Acre:

The amount of pesticide formulation sprayed per acre is determined by multiplying the quantity of formulation (ounces/pounds/pints/cups/teaspoons/tablespoons/etc.) mixed per gallon of water, times the number of gallons sprayed per acre.
(Quantity of Formulation Per Gallon) x (Gallons Sprayed Per Acre) = Formulation Sprayed Per Acre
Example: (1/2 pound per gallon) x (12 gallons per acre) = 6 pounds per acre

Amount of Active Ingredients Sprayed Per Acre:

To calculate the amount of active ingredients (AI) applied per acre, multiply the amount (pounds, gallons, ounces, etc) of pesticide formulation required per acre, times the percentage of active ingredients in the formulation (100%, 75%, 50%, 25%, etc.), and divide the value by 100.

$$\frac{\text{(Amount of Formulation Required Per Acre) x (Percentage of AI)}}{100} = \text{Active Ingredients Per Acre}$$

Example: $$\frac{\text{(4 pounds formulation sprayed per acre) x (75\% AI)}}{100} = \text{3 pounds of AI sprayed per acre}$$

Note: 75 % = 0.75

To Calculate the Gallons of Pesticide Mixture Sprayed Per Acre:

The amount of pesticide mixture sprayed per acre is determined by dividing the number of gallons sprayed by the number of acres sprayed.

$$\frac{\text{Gallons Sprayed}}{\text{Acres Sprayed}} = \text{Gallons Sprayed Per Acre}$$

Example: $$\frac{\text{200 Gallons Sprayed}}{\text{10 Acres Sprayed}} = \text{20 gallons of pesticide mixture sprayed per acre}$$

APPENDICES

Page

Appendix 1. Utah Major Insect Pests By Crop

The following lists include insects and other arthropods.

Field Crop Insects

Alfalfa

Alfalfa caterpillar
Alfalfa weevil (majority of insect pest damage in Utah alfalfa caused by this insect.)
Army cutworm
Blue aphid
Pea aphid
Spotted alfalfa aphid
Variegated cutworm
Grasshoppers (Utah's 10 primary species)

- Big-headed grasshopper
- Clear-winged or warrior grasshopper
- Differential grasshopper *
- Lubber grasshopper
- Migratory grasshopper *
- "P. quad" grasshopper
- Packard grasshopper *
- Red-legged grasshopper *
- Two-striped grasshopper *
- White-whiskers grasshopper

(* Ninety percent of the grasshopper damage in Utah is caused by these five grasshoppers.)

Small Grains

Army cutworm
Army worm
Banks grass mite
Brown wheat mite
Cereal leaf beetle
False wireworm
Flea beetle
Grasshopper
Greenbug
Hessian fly
Russian wheat aphid
Wheat-stem maggot
White grub

Corn and Sorghum

Corn earworm
Corn flea beetle
Corn-leaf aphid
Corn rootworm
Cutworms
European corn borer
Red spider mite
Sorghum greenbug

Dry Bean

Bean-leaf beetle
Mexican bean beetle
Western bean cutworm

Fruit Tree Insects

Apple

Campylomma bug
Codling moth
Cutworm
European red mite
Leafroller (obliquebanded, fruit tree, pandemis)
Lygus bug
Green apple aphid
Rosy apple aphid
San Jose scale
Spider mite (twospotted and McDaniel)
Stink bug
Fruitworm (green, pyramidal, others)
Western flower thrip
Western tentiform leafminer
White apple leafhopper
Woolly apple aphid

Apricot

European red mite
Green peach aphid
Lygus bug
Oriental fruit moth
Peach silver mite
Peach twig borer
Peachtree (crown) borer
San Jose scale
Spider mite (twospotted and McDaniel)
Stink bug

Cherry

Black cherry aphid
Cherry/pear slug
Cutworm
European red mite
Leafroller
Prunus rust mite
San Jose scale
Shothole borer
Spider mite (twospotted and McDaniel)
Western cherry fruit fly

Peach/Nectarine

Box Elder bug
Cutworm
European red mite
Green peach aphid
Lygus bug
Peach silver mite
Peach twig borer
Peachtree (crown) borer
San Jose scale
Spider mite (twospotted and McDaniel)
Stink bug
Oriental fruit moth
Western flower thrip

Pear

European red mite
Codling moth
Cutworm
Leafroller
Lygus bug
Pear/cherry slug
Pear leaf blister mite
Pear psylla
Pear rust mite
San Jose scale
Spider mite (twospotted and McDaniel)
Stink bug

Vegetable Insects

Soil
Flea beetle
Root weevil
White grub
Wireworm

Piercing-Sucking
Aphid (many species)
Leafhopper (many species)
Spider mite
Stink bug
Squash bug
Thrip
Whitefly

Noninsect chewing pests:
Sowbug, snail, and slug

Chewing
Armyworm
Cabbage looper
Click beetle
Wireworm
Corn earworm
Tomato fruitworm
Corn rootworm
Colorado potato beetle
Cutworm
Diamond-back moth
European earwig
Flea beetle
Grasshopper
Imported cabbage worm
Mexican bean beetle
Root weevil
Striped and spotted cucumber beetle

Rangeland Insects

Black grass bug
Grasshopper (See list under alfalfa insects.)
The majority of grasshopper crop damage is the result of grasshopper migrations from rangeland to cropland.
Mormon cricket

Beneficial Arthropods

Ambush bug
Big-eyed bug
Damsel bug
Ground beetle
Hover fly (Syrphidae)
Lacewing
Lady beetle (Coccinellidae)
Minute pirate bug
Parasitic wasp
Praying mantis
Predaceous midge
Predaceous mite (Phytoseiidae)
Spider

Web sites with pictures and information for insects and other arthropods.
www.reeusda.gov/nipmn/
www.extension.umn.edu/
ippc.orst.edu/oregonIPM.html
www.crop-net.com/insct-id.html
axp.ipm.ucdavis.edu/default.html
www.sdvc.uwyo.edu/grasshopper
www.extension.uiuc.edu/pubs.html
www.ext.usu.edu/ag/ipm/index.htm
www.agnr.umd.edu/users/hgic/home.html
www.entomology.wisc.edu/mbcn/bcn.html
www.uidaho.edu/ag/environment/ipm/index.html

Appendix 2. Utah Noxious and Restricted Weeds and Seeds

Utah Noxious Weed Act R68-8 lists the following noxious weeds

Bermudagrass	(*Cynodon dactylon variety dactylon*) Bermudagrass is not a noxious weed in Washington County
Bindweed (Wild morning glory)	(*Convolvulus, species plural*)
Broadleaved peppergrass (Tall whitetop)	(*Lepidium latifolium*)
Canada thistle	(*Cirsium arvense*)
Diffuse knapweed	(*Centaurea diffusa*)
Dyers woad	(*Isatis tinctoria*)
Leafy spurge	(*Euphorbia esula*)
Medusahead	(*Taeniatherum caput medusae subspecies caput-medusae*)
Musk thistle	(*Carduus nutans*)
Perennial sorghum, species plural	(*Sorghum halepense*) and (*Sorghum almum*) Including but not limited to Johnson grass
Purple loosestrife	*(Lythrum Salicaria)*
Quackgrass	(*Elytrigia repens*)
Russian knapweed	(*Acroptilon repens*)
Scotch thistle (Cotton thistle)	(*Onopordum acanthium*)
Spotted knapweed	(*Centaurea maculosa*)
Squarrose knapweed	(*Centaurea virgata subspecies squarrosa*)
Whitetop	(*Cardaria, species plural*)
Yellow starthistle	(*Centaurea solsitialis*)

Utah Seed Law R68-8 lists the following prohibited noxious weed seeds

Bermudagrass	(*Cynodon dactylon variety dactylon*) Bermudagrass is not a noxious weed in Washington County
Bindweed (Wild morning glory)	(*Convolvulus, species plural*)
Broadleaved peppergrass (Tall whitetop)	(*Lepidium latifolium*)
Canada thistle	(*Cirsium arvense*)
Diffuse knapweed	(*Centaurea maculosa*)
Dyers woad	(*Isatis tinctoria*)
Leafy spurge	(*Euphorbia esula*)
Medusahead	(*Taeniatherum caput medusae subspecies caput-medusae*)
Musk thistle	(*Carduus nutans*)
Perennial sorghum, species plural	(*Sorghum halepense*) and (*Sorghum almum*) Including but not limited to Johnson grass
Purple loosestrife	*(Lythrum Salicaria)*
Quackgrass	(*Elytrigia repens*)
Russian knapweed	(*Acroptilon repens*)
Scotch thistle (Cotton thistle)	*(Onopordum acanthium*)
Spotted knapweed	*(Centaurea maculosa*)
Squarrose knapweed	*(Centaurea virgata subspecies squarrosa*)
Whitetop	(*Cardaria, species plural*)
Yellow starthistle	(*Centaurea solsitialis*)

Utah Seed Law R68-8 lists the following restricted weed seeds

Dodder	(*Cuscuta spp*.)
Halogeton	(*Halogeton glomeratus*)
Jointed goatgrass	(*Aegilops cylindrica*)
Poverty weed	(*Iva axillaris*)
Wild oats	(*Avena fatua*)

Appendix 3. Utah Major Plant Diseases By Crop

Alfalfa
Common and head smut
Root and crown rot
Stem nematode
Verticillium (most serious alfalfa disease)

Small Grains
Barley yellow dwarf virus
Bunt
Root and foot rot
Smuts
Tan spot

Corn and Sorghum
Fusarium stalk rot
Head smut

Fruit Tree
Bacterial blast
Coryneum blight
Cytospora canker
Fire blight
Pear decline
Phytophthora root rot
Powdery mildew
Stem pitting virus

Sugar Beets
Cercospora leaf blight
Powdery mildew
Sugar beet nematode

Dry Bean
Bacterial diseases: halo blight, bacterial brown spot, and common bacterial blight
Rust
White mold

Potato
Blackleg
Early blight

Cole Crops (like cabbage) and Lettuce
Blackleg
Black rot
Bottom rot

Cucurbit
Angular leaf spot
Bacterial wilt
Cucumber mosaic virus

Onion
Botrytis neck rot
Fusarium basal rot
Pinkroot

Pepper
Mosaic virus
Phytophthora wilt

Spinach
Downy mildew
Rusts

Tomato
Early blight
Fusarium wilt
Spotted wilt virus

GLOSSARY OF TERMS

A

ABSORPTION - The process by which pesticides are taken into plants by roots or foliage (stomata, cuticle, etc.).

ADJUVANT - Material added to a pesticide mixture to improve or alter the deposition, toxic effects, mixing ability, persistence, or other qualities of the active ingredient.

ADSORPTION - The adhesion of pesticide spray droplets to the plant's surface.

ANNUAL - A plant that completes its life cycle within one year, then dies.

ANTIBIOTIC - Chemical substance produced by one micro-organism that inhibits or kills other micro-organisms.

AQUIFER - Underground formation of sand, gravel, or porous rock that contains water; the place where groundwater is found.

AROMATICS - Compounds derived from the hydrocarbon benzene (C_6H_6).

B

BACTERICIDE - Pesticide that inhibits or kills bacteria or prevents their growth.

BACTERIUM - Single-celled microscopic plant that lacks chlorophyll.

BAND APPLICATION - An application of spray or dust to a continuous restricted area such as in or along a crop row rather than over the entire field.

BASAL TREATMENT - Applied to encircle the stem of a plant above and at the ground such that foliage contact is minimal. A term used mostly to describe treatment of woody plants.

BIENNIAL - Plant that completes its growth in two years. The first year, it produces leaves and stores food; the second year, it produces fruits and seeds.

BIOLOGICAL CONTROL - control of pests by means of predators, parasites, disease-producing organisms, competitive microorganisms, or decomposing plant material which reduce the population of the pathogen.

BLIGHT - Disease characterized by general and rapid killing of leaves, flowers and stems.

BLOTCH - Disease characterized by large, irregular spots or blots on leaves, shoots, stems and fruits.

BROADCAST TREATMENT - Application of a pesticide over an entire field area.

C

CANKER - Necrotic, often sunken lesion on a stem, branch or twig.

CARRIER - The liquid or solid material added to an active ingredient to facilitate its storage, shipment, or use in the field.

CHLOROSIS - Yellowing of normally green tissue due to chlorophyll destruction or failure of chlorophyll formation.

COMPATIBLE - Quality of two compounds that permits them to be mixed without effect on the properties of either.

CONCENTRATION - The amount of active material in a given volume of diluent.

CONTACT HERBICIDE - Herbicide that causes localized injury to plant tissue when contact occurs.

CORTEX - All tissues outside the xylem of a plant stem or root.

COTYLEDON - The first leaf or leaves of a growing plant embryo.

COTYLEDON LEAVES - The first leaf or pair of leaves of the embryo of seed plants.

CROWN - The point where stem and root join in a seed plant.

CUTICLE - The outer protective covering of plants which aids in preventing water loss.

D

DAMPING-OFF - Destruction of seedlings near the soil line resulting in wilt and death.
DEGRADATION - The breakdown of a pesticide into an inactive or less active form. Environmental conditions, microorganisms, or other chemicals can contribute to the degradation of pesticides.
DIEBACK - Progressive death of shoots, branches and roots generally starting at the tip.
DIRECTED APPLICATION - Precise application to a specific area or plant organ such as to a row or bed or to the leaves or stems of plants.
DISEASE - Any malfunctioning of host cells and tissue that results from continuous irritation by a pathogenic agent or environmental factor and that leads to the development of symptoms.
DORMANCY - State of inhibited germination of seeds or growth of plant organs. A state of suspended development.

E

EFFICACY - The ability of a pesticide to produce a desired effect on a target organism.
EMERGENCE - Appearance of the first part of the crop plant above the ground.
EMULSIFYING AGENT - Material which facilitates the suspending of one liquid in another.
EMULSION - Mixture in which one liquid is suspended in tiny globules in another liquid; for example, oil in water.
ENATION - Raised, corrugated outgrowths chiefly of a biotic disease.
ERADICATION - Pest management strategy that attempts to eliminate all members of a pest species.
ETIOLATION - Elongation and yellowing or blanching of a green plant through lack of sunlight. Stem internodes may be elongated.
EXUDATE - Substance, usually liquid, discharged from a plant or animal through a natural opening or from diseased tissue through a wound.

F

FALLOW - Cultivated land that is allowed to lie dormant during a growing season.
FOLIAR APPLICATION - Pesticide application to plant leaves or foliage.
FORMULATION - Pesticide prepared by the manufacturer requiring dilution prior to application.
FRUITING BODY - Complex fungus structure that contains spores. Characteristic types aid in fungus identification.
FUMIGANT - Gaseous or readily volatilized pesticide.
FUNGICIDE - Pesticide used to control, suppress, or kill plant disease agents or severely interrupt their normal growth.
FUNGUS - Organism with no chlorophyll that reproduces by sexual or asexual spores usually with mycelium.

G

GALL - Swelling or overgrowth produced on a plant as a result of infection by certain pathogens.
GERMINATION - The beginning process when a plant sprouts from a seed.
GRANULAR - Dry formulation of pesticide and other components in discrete particles generally less than ten cubic millimeters in size.
GROWTH STAGES - (1) tillering stage: when a plant produces additional shoots from a single crown, as in wheat. (2) jointing stage: when the internodes of the stem are elongating. (3) boot stage: when the seedhead of a plant begins to emerge from the sheath (usually grain crops).

H

HERBICIDE - Pesticide used to control, suppress or kill plants or severely interrupt their normal growth processes.
HOST - Plant or animal that is invaded by a parasite and from which the parasite gets its nutrients.
HYPHA - Single branch of a fungus mycelium.

I

IMPERFECT STAGE - Part of the life cycle of a fungus in which no sexual spores are produced.
INCUBATION PERIOD - Period of time between penetration of a host by a pathogen and the first
appearance of symptoms on the host.
INFECTION - Establishment of a pathogen within a host.
INHIBIT - To prevent something from happening, such as a biological reaction within the tissues of a plant or animal.
INOCULUM - Infectious pathogen or its spores, mycelium, or virus, bacteria or mycoplasma particles that are capable of infecting plants or animals.
INSECTICIDE - Chemical used to control, suppress or kill insects or severely interrupt their normal growth processes.

L

LEACHING - Process by which some pesticides move down through the soil, usually by being dissolved in water, with the possibility of reaching groundwater.
LESION - Localized area of discolored, diseased tissue.

M

MERISTEMATIC TISSUE - Plant tissue that is in the process of actively growing and dividing, such as those at the apex of growing stems and roots.
MILDEW - Fungal disease in which the mycelium and spores are seen as a whitish growth on the host surface.
MODE OF ACTION - The way a pesticide reacts with a pest organism to destroy it.
MOLD - Any profuse or woolly fungus growth on damp or decaying matter or on surfaces of host tissue.
MOSAIC - Variegated pattern of greenish and yellowish shades in leaves usually caused by a disruption of the chlorophyll content.
MOTTLE - Irregular pattern of indistinct light and dark areas.
MYCELIUM - Mass of interwoven threads (hyphae) that make up the vegetative body of a fungus.

N

NECROSIS - Death of plant cells usually resulting in the affected tissue turning brown or black.
NEMATICIDE - Pesticide that inhibits or kills nematodes.
NEMATODE - Non-segmented, microscopic round worm usually threadlike and free living or parasitic on plants.
NON SELECTIVE HERBICIDE - Herbicide that is generally toxic to plants, without regard to species. Toxicity may be a function of dosage, method of application, etc.
NOXIOUS - Something that is harmful to living organisms, such as noxious weeds.

O

OBLIGATE PARASITE - Parasite that in nature can grow and multiply only on or in living organisms.

P

PARASITE - An organism that lives on or in a living host and that gets all or part of its nutrients from the host.

PARTICLE DRIFT - Spray particles which are carried away from the application area by air movements at the time of or soon after application.
PATHOGEN - Any organism capable of causing disease. Most pathogens are parasites.
PERFECT STAGE - Period of life during which a fungus produces sexual spores.
PELLET - Dry formulation of pesticide and other components in discrete particles, usually larger than ten cubic millimeters.
PERENNIAL - Plant that lives from year to year, but for three years or more under normal growing conditions.
PERSISTENT HERBICIDE - Herbicide which will harm crops planted in rotation after harvesting the treated crop, or which interferes with regrowth of native vegetation in non-crop sites for an extended period of time. (See residual herbicide.)
pH - Measure of a solution's acidity or alkalinity; 7 is numerically equal to a neutral solution, pH increases with increasing alkalinity, while pH decreases with increasing acidity.
PHOTOSYNTHESIS - Process by which plants convert sunlight into energy.
PHYTOPLASMAS - Forms of life intermediate between viruses and bacteria. They lack an organized nucleus and cell wall and are transmitted by leafhoppers.
PHYTOTOXIC - Injurious to plants. Excesses of pesticides and fertilizers can be phytotoxic.
PLANT-GROWTH REGULATOR - Substance used for controlling or modifying plant-growth processes without appreciable phytotoxic effect.
POST-EMERGENCE TREATMENT - Application after emergence of the weed or planted crop.
PRE-EMERGENCE TREATMENT - Application before emergence of the weed or planted crop.
PRE PLANT TREATMENT - Application before the crop is planted.
PROTECTANT - Pesticide applied to a plant in advance of the pathogen to prevent infection.
PUSTULE - Small blister-like elevation of epidermis created as spores form underneath and push outward.

R

RATE - The amount of pesticide material applied per unit area or per unit volume.
RESISTANCE - Inherent ability of a host to suppress, retard or prevent entry or subsequent activity of a pathogen or other injurious factor.
RESIDUAL HERBICIDE - Herbicide that persists in the soil and injures or kills germinating weed seedlings over a relatively short period of time. (See persistent herbicide.)
RHIZOME - Underground stem capable of sending out roots and leafy shoots.
RING SPOT - Circular area of chlorosis with a green center; a symptom of various virus diseases.
ROSETTE - Short, bunchy habit of plant growth.
RUNOFF - The liquid spray material that drips from the foliage of treated plants or from other treated surfaces. Also, the rainwater or irrigation water that leaves an area and may contain trace amounts of pesticide.
RUSSET - Brownish, roughened areas on the skin of fruit resulting from cork formation.

S

SANITATION - Term used for cultural methods that reduce inoculum.
SAPROPHYTE - Organism that feeds on dead organic matter as opposed to a parasite that feeds on living tissue.
SCAB - Roughened, crust-like diseased area on the surface of a plant organ.

SELECTIVE HERBICIDE - Herbicide that is more toxic to some plant species than to others.

SOIL APPLICATION - Pesticide applied mainly to the soil surface rather than to vegetation.

SOIL MOBILITY - Variable characteristic of a pesticide based on its chemical nature. Highly mobile pesticides leach rapidly through the soil and may contaminate groundwater. Immobile pesticides or those with low soil mobility remain attached to soil particles and are resistant to leaching.

SOIL STERILANT - Material which renders the soil incapable of supporting plant growth. Sterilization may be temporary or practically permanent.

SPORE - Tiny propagative unit of a fungus that functions as a seed but differs by not containing a pre-formed embryo.

SPOT TREATMENT - Pesticide applied over small, restricted area(s), of a larger area such as the treatment of weed patches within a larger field.

SPRAY DRIFT - The movement of airborne spray particles from the spray nozzle beyond the intended contact area.

STELE - The central cylinder inside the cortex of roots and stems of vascular plants.

STOLON - Runners or stems that develop roots and shoots at the tip or nodes, as in the strawberry plant.

STOOL - To throw out shoots; to tiller.

STYLET - The hollow feeding spear of a nematode.

SURFACTANT - Material which in pesticide formulations imparts emulsifiability, spreading, wetting, dispersability, or other surface-modifying properties.

SUSCEPTIBILITY - Magnitude or capacity to react to pesticide treatment.

SUSPENSION - Liquid or gas in which very fine solid particles are dispersed but not dissolved.

SYMPTOM - The external and internal reactions or alterations of a host as a result of a disease.

SYSTEMIC - Pesticide absorbed or injected into the plant and then spread internally through the plant.

T

TOTAL VEGETATION APPLICATION - Applying of single or multiple pesticide at one time or in sequence to provide pre-emergent and/or post emergent control of all plants. The term usually involves application to noncrop areas.

TRANSLOCATED HERBICIDE - Herbicide that is moved within the plant. Translocated herbicides may be either phloem-mobile or xylem-mobile, but the term is often used in a more restrictive sense to refer to herbicides that are moved in the phloem.

V

VASCULAR - The term applied to the water and nutrient conducting tissue of plants, also applied to a pathogen that grows in these conductive tissues.

VAPOR DRIFT - The movement of pesticide vapors from the area of application. Some pesticides, when applied at normal rates and normal temperatures, have a sufficiently high vapor pressure to cause them to change into vapor form. This may cause injury to susceptible plants away from the site of application. Note: Vapor injury and injury from spray drift are often hard to tell apart.

VIABLE - Alive, especially with reference to seeds capable of germinating.

VIROID - Low molecular weight ribonucleic acid (RNA) capable of infecting certain host cells, replicating, and causing disease.

VIRULENCE - The relative capacity and power of a pathogen to cause disease.

VIRUSES - Submicroscopic, filterable, obligate parasites. They are high molecular weight nucleoproteins capable of multiplying and acting like living organisms in plant or animal cells.
VOLATILE - Quality that makes a compound evaporate or vaporize (change from a liquid to a gas) at ordinary temperatures on exposure to air.

W

WATER SOLUBLE CONCENTRATE - Liquid pesticide formulation that dissolves in water to form a true solution.
WETTING AGENT - Surfactant which, when added to a spray solution, causes it to spread over and wet plant surfaces more thoroughly.
WILT - Loss of rigidity and drooping of plant parts, generally caused by insufficient water in the plant.

Y

YELLOWS - Plant disease characterized by yellowing and stunting of the host plant.